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FOR: INK JET HEAD AND RECORDING APPARATUS USING THE SAME

CERTIFICATION OF TRANSLATION

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SIR:

I, Teiichiro OGAWA, residing at c/o ION Patent of HAYAKAWA-TONAKAI BLDG. 3F, 12-5, IWAMOTO-CHO 2-CHOME, CHIYODA-KU, TOKYO, 101-0032 JAPAN declare:

(1) that I know well both the Japanese and English languages;

(2) that I translated the attached document identified as corresponding to Japanese Application No.2003-020585 filed in Japan on January 29, 2003 from Japanese to English;

(3) that the attached English translation is a true and correct translation of the document attached thereto to the best of my knowledge and belief; and

(4) that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both under 18 USC 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: June 14, 2006

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PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this Office.

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No. 2003-020585

[ST.10/C]: [JP 2003-020585]

Applicant: Fuji Photo Film Co., Ltd.

September 8, 2003

Commissioner,
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[LIST OF ATTACHED DOCUMENT]

[TYPE OF DOCUMENT]	Specification	1 set
[TYPE OF DOCUMENT]	Drawing	1 set
[TYPE OF DOCUMENT]	Abstract	1 set
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[REQUEST FOR PROOF] YES

[TYPE OF THE DOCUMENT] Specification

[TITLE OF THE INVENTION] Electrostatic ink jet head, and recording apparatus and recording method using the same

[CLAIMS]

[Claim 1]

An electrostatic ink jet head for recording an image on a recording medium by ejecting ink containing charged fine particles by means of an electrostatic force, comprising:

an ink guide whose tip end portion is directed toward a side of said recording medium;

an ink flow path that supplies the ink to said ink guide; and

an ejection electrode that comprises a surrounding electrode arranged so as to surround an outer periphery of said ink guide with a distance, and ejects the ink guided from said ink flow path to the tip end portion of said ink guide by means of the electrostatic force, characterized in that:

a ratio between an effective inside diameter of said surrounding electrode and a distance from said surrounding electrode to a tip end of said ink guide protruding on the side of said recording medium is set in a range of 1:0.5 to 1:2.

[Claim 2]

The electrostatic ink jet head according to Claim 1,

wherein the ratio between an effective inside diameter of said surrounding electrode and a distance from said surrounding electrode to a tip end of said ink guide is set in a range of 1:0.7 to 1:1.7.

[Claim 3]

An electrostatic ink jet head for recording an image on a recording medium by ejecting ink containing charged

fine particles by means of an electrostatic force, comprising:

an ink guide whose tip end portion is directed toward a side of said recording medium;

an ink flow path that supplies the ink to said ink guide; and

an ejection electrode that comprises side-by-side electrodes arranged on both sides of said ink guide so as to oppose each other with a distance, and ejects the ink guided from said ink flow path to the tip end portion of said ink guide by means of the electrostatic force, characterized in that:

a ratio between an effective distance between said side-by-side electrodes and a distance from said side-by-side electrodes to a tip end of said ink guide protruding on the side of said recording medium is set in a range of 1:0.7 to 1:2.8.

[Claim 4]

The electrostatic ink jet head according to Claim 3,

wherein the ratio between an effective distance between said side-by-side electrodes and a distance from said side-by-side electrodes to a tip end of said ink guide is set in a range of 1:1.0 to 1:2.4.

[Claim 5]

The electrostatic ink jet head according to any one of Claims 1 to 4, wherein:

said ink guide is arranged on a head substrate;

said ink flow path is formed between said head substrate and an insulating substrate arranged so as to be spaced apart from said head substrate by a predetermined distance;

a plurality of through holes are formed in said insulating substrate; and

said ink guide has said tip end portion protruding on the side of said recording medium from one of the through holes formed in said insulating substrate and guides the ink flowing in said ink flow path from said ink flow path to said tip end portion.

[Claim 6]

An electrostatic ink jet recording apparatus, characterized by comprising:

the electrostatic ink jet head according to any one of Claims 1 to 5;

means for holding said recording medium;

means for relatively moving said ink jet head and said recording medium;

means for applying a predetermined bias voltage between said ejection electrode and said recording medium; and

means for applying a predetermined ejection voltage to said ejection electrode in accordance with said image to be recorded on said recording medium.

[Claim 7]

An electrostatic ink jet recording method, characterized by comprising:

applying a predetermined bias voltage between said ejection electrode of the electrostatic ink jet head according to any one of Claims 1 to 5 and said recording medium;

moving said ink jet head relative to said recording medium;

applying a predetermined ejection voltage to said ejection electrode in accordance with said image to be recorded on said recording medium;

ejecting concentrated ink in a tip end portion of said ink guide of said ink jet head; and

recording said image on said recording medium.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

The present invention relates to an electrostatic ink jet head that controls ejection of ink containing charged fine particles by means of an electrostatic force, and a recording apparatus and a recording method using the ink jet head.

[0002]

[Prior Art]

The electrostatic ink jet recording system is a system in which ink containing a charged fine particle component is used and an image corresponding to image data is recorded on a recording medium by controlling ejection of the ink by means of an electrostatic force through application of a predetermined voltage to each ejection electrode of an ink jet head in accordance with the image data. As a recording apparatus adopting this electrostatic ink jet recording system, there are known ink jet recording apparatuses as disclosed in, for example, Patent Document 1, Patent Document 2, and Patent Document 3.

[0003]

Fig. 16 is a conceptual diagram schematically showing an example of an outlined construction of an ink jet head of the ink jet recording apparatus disclosed in Patent Document 1. An ink jet head 100 shown in the drawing includes a head substrate 102, an ink guide 104, an insulating substrate 106, an ejection electrode 108, a counter electrode 110 supporting a recording medium P, a bias voltage source 112, and a signal voltage source 114. Note that in this drawing, only one individual electrode

serving as an ejection means constituting the ink jet head disclosed in Patent Document 1 is conceptually illustrated.

[0004]

Here, the ink guide 104 is made of a resin flat plate having a predetermined thickness and including a protrusion-like tip end portion 104a, and is arranged on the head substrate 102. Also, in the insulating substrate 106, a through hole 116 is formed at a position corresponding to a position at which the ink guide 104 is arranged. The ink guide 104 passes through the through hole 116 formed in the insulating substrate 106 and its tip end portion 104a protrudes upward from the upper surface of the insulating substrate 106 in the drawing, that is, from a surface thereof on a recording medium P side. Also, the head substrate 102 and the insulating substrate 106 are arranged so as to be spaced apart from each other by a predetermined distance, and a flow path 118 of ink Q is formed therebetween.

[0005]

Also, the ejection electrode 108 is provided in a ring shape for each individual electrode on the upper surface of the insulating substrate 106 in the drawing so as to surround the through hole 116 formed in the insulating substrate 106. The ejection electrode 108 is connected to the signal voltage source 114 that generates a pulse signal corresponding to ejection data (ejection signal) such as image data or print data, and the signal voltage source 114 is grounded through the bias voltage source 112.

In addition, the counter electrode 110 is arranged at a position opposing the tip end portion 104a of the ink guide 104 and is grounded. Also, the

recording medium P is arranged on the lower surface of the counter electrode 110 in the drawing, that is, on a surface thereof on an ink guide 104 side, and the counter electrode 110 functions as a platen of the recording medium P.

[0006]

In the ink jet head 100 constructed in this manner, at the time of recording, ink containing a fine particle component charged to the same polarity as a voltage applied to the ejection electrode 108 is circulated by a not-shown ink circulation mechanism in a predetermined direction (from the right to the left, in the illustrated example) in the ink flow path 118, and a part of the ink Q in the ink flow path 118 is supplied to the tip end portion 104a of the ink guide 104 through the through hole 116 in the insulating substrate 106 by capillary action or the like.

[0007]

Here, a predetermined high voltage, e.g., DC voltage of 1.5 kV, is constantly applied to the ejection electrode 108 by the bias voltage source 112. Under this state, the strength of an electric field in proximity to the tip end portion 104a of the ink guide 104 is low and the ink Q supplied to the tip end portion 104a of the ink guide 104 will not fly out from the tip end portion 104a. In this case, however, a part of the ink Q in the ink flow path 118, in particular, the charged fine particle component moves upward above the upper surface of the insulating substrate 106 in the drawing while passing through the through hole 116 in the insulating substrate 106 and aggregates in the tip end portion 104a of the ink guide 104.

[0008]

On the other hand, when a pulse voltage, e.g., DC voltage of 500 V (ON-time; 0 V: OFF-time) is applied by the signal voltage source 114 to the ejection electrode 108 biased to the high voltage (DC 1.5 kV) by the bias voltage source 112, both of these high voltages are superimposed on each other and 2 kV is applied to the ejection electrode 108, for instance. As a result, the ink Q, in particular, the charged fine particle component in the ink Q further moves upward along the ink guide 14 and aggregates in the tip end portion 104a. Then, the ink Q aggregating in the tip end portion 104a of the ink guide 14 and containing the charged fine particle component flies out from the tip end portion 104a by means of an electrostatic force, is attracted by the grounded counter electrode 110, and adheres on the recording medium P. In this manner, a dot is formed by the charged fine particle component.

[0009]

By forming dots of the charged fine particle component in this manner while relatively moving the ink jet head 100 and the recording medium P supported on the counter electrode 110, an image corresponding to image data is recorded on the recording medium P.

[0010]

Meanwhile, in Patent Document 2, an image forming apparatus is disclosed which uses a head obtained by providing a control electrode below the ink flow path 118 in the ink jet head 100 described above. During recording, this control electrode causes the ink Q in the ink flow path 118, in particular, the charged fine particle component in the ink Q to migrate toward the ejection electrode 108 and further toward the tip end portion 104a of the ink guide 104. On the other hand,

during non-recording, the control electrode causes the ink Q adhering to the ink guide 104 and the charged fine particle component in the ink Q to migrate toward a lower portion of the ink flow path 118.

Also, in Patent Document 3, an ink jet head is disclosed in which parallel ejection electrodes (parallel electrodes) provided in a groove-like ink flow path are used in place of the ring-like ejection electrode (circular electrode) disclosed in Patent Document 1, and Patent Document 2.

[0011]

By the way, even when the ink jet heads disclosed in Patent Document 1, Patent Document 2, and Patent Document 3 described above are used, in the case of a recording apparatus that is required to perform high-definition recording at a high speed, a line head is necessary, which is capable of recording images of one line at a time inevitably. When the definition and recording speed of the recording apparatus are respectively 1200 dpi (dot/inch) and 60 ppm (page/minute), for instance, a line head that is capable of recording an image on a recording medium having a width of 10 inches needs to include as numerous as 12000 individual electrodes, whose number is equal to the number of pixels on one line, and pulse voltage sources, that is, drive circuits whose number is equal to the number of the individual electrodes to be driven.

[0012]

In this case, in the line head, the individual electrodes and the pulse voltage sources need to be implemented at a physically extremely high density with respect to the line direction. The pulse voltage sources use a high voltage (around 400 to 600 V, for instance),

so that when the individual electrodes and the pulse voltage sources are arranged at a high density, there involves a high risk of causing the discharge. Accordingly, it is extremely difficult to cope with both high-density implementation and high-voltage driving. Note that in order to apply pulse voltages to the ejection electrodes, the pulse voltage sources are required to generate the pulse voltages. Here, the ejection electrodes are each a small electrode, so that the amount of a current consumed by ejection itself is small. However, if high pulse voltages are generated by the pulse voltage sources, current consumption is increased. Also, the pulse voltage sources consume currents in order to generate the pulse voltages, so that if high pulse voltages are generated, the current consumption is increased. When the number of individual electrodes is small, the increased current consumption causes little problem. However, when a large number of individual electrodes are used as described above, the increased current consumption causes a problem.

[0013]

[Patent Document 1]

JP 10-138493 A

[Patent Document 2]

JP 11-078026 A

[Patent Document 3]

JP 09-254372 A

[0014]

[Problems to be Solved by the Invention]

The present invention has a first object to provide an electrostatic ink jet head capable of achieving an ejection voltage reduction, widening a selection range for ink guide materials (low dielectric constant material

becomes usable, for instance), and widening a selection range for ink guide tip end structures.

It is a second object of the present invention to provide a safe, low-cost, and widely applicable electrostatic ink jet recording apparatus and recording method that are capable of recording an image on a recording medium with stability by using the electrostatic ink jet head described above which achieves the first object of the present invention.

[0015]

[Means to Solve the Problems]

In order to attain the first object described above, a first aspect of the present invention provides an electrostatic ink jet head for recording an image on a recording medium by ejecting ink containing charged fine particles by means of an electrostatic force, including: an ink guide whose tip end portion is directed toward a side of the recording medium; an ink flow path that supplies the ink to the ink guide; and an ejection electrode that includes a surrounding electrode arranged so as to surround an outer periphery of the ink guide with a predetermined spacing, and ejects the ink guided from the ink flow path to the tip end portion of the ink guide by means of the electrostatic force, characterized in that a ratio between an effective inside diameter of the surrounding electrode and a distance from the surface of the surrounding electrode to a tip end of the ink guide protruding on the side of the recording medium is set in a range of 1:0.5 to 1:2.

Preferably, the ratio between the effective inside diameter of the surrounding electrode and the distance from the surface of the surrounding electrode to the tip end of the ink guide is set in a range of 1:0.7 to 1:1.7.

Preferably, the surrounding electrode is a substantially circular electrode, and the effective inside diameter is an average inside diameter, and more preferably, the surrounding electrode is a circular electrode, and the effective inside diameter is an inside diameter.

[0016]

In order to attain the first object described above, a second aspect of the present invention provides an electrostatic ink jet head for recording an image on a recording medium by ejecting ink containing charged fine particles by means of an electrostatic force, including: an ink guide whose tip end portion is directed toward a side of the recording medium; an ink flow path that supplies the ink to the ink guide; and an ejection electrode that includes side-by-side electrodes arranged on both sides of the ink guide so as to oppose each other with a predetermined spacing, and ejects the ink guided from the ink flow path to the tip end portion of the ink guide by means of the electrostatic force, characterized in that a ratio between an effective spacing between the side-by-side electrodes and a distance from the surface of the side-by-side electrodes to a tip end of the ink guide protruding on the side of the recording medium is set in a range of 1:0.7 to 1:2.8.

Preferably, the ratio between the effective spacing between the side-by-side electrodes and the distance from the surface of the side-by-side electrodes to the tip end of the ink guide is set in a range of 1:1.0 to 1:2.4.

Preferably, the side-by-side electrodes are substantially parallel electrodes, and the effective spacing is an average electrode spacing, and more preferably, the side-by-side electrodes are parallel

electrodes, and the effective spacing is an electrode spacing.

[0017]

In each aspect, it is preferable that the ink guide is arranged on a head substrate; the ink flow path is formed between the head substrate and an insulating substrate arranged so as to be spaced apart from the head substrate by a predetermined distance; a plurality of through holes are formed in the insulating substrate; and the ink guide has the tip end portion protruding on the side of the recording medium from one of the through holes formed in the insulating substrate and guides the ink flowing in the ink flow path from the ink flow path to the tip end portion.

[0018]

Also, preferably, the ink guide is supported by the partition walls arranged face to face at a predetermined interval across the ink flow path; the parallel electrodes are respectively arranged on the surfaces of the insulating supporting substrates arranged face to face at a predetermined interval; the ink flow path is formed between the partition walls arranged face to face at a predetermined interval, and the parallel electrodes and the insulating supporting substrates, which are arranged face to face at a predetermined interval; and the tip end portion of the ink guide protrudes from opened ends of the ink flow path toward the recording medium side to guide the ink flowing in the ink flow path from the ink flow path to the tip end portion.

[0019]

Preferably, the ejection electrode is arranged on the surface of the insulating substrate.

Preferably, the ejection electrode includes: a first

drive electrode arranged closer to a side of the insulating substrate than the ink flow path and a second drive electrode arranged closer to a side of the head substrate than the first drive electrode. Preferably, the first drive electrode is arranged on one surface of the insulating substrate in the side of the recording medium, and the second drive electrode is arranged on another surface of the insulating substrate in the side of the head substrate. Preferably, the second drive electrode is a common electrode to be common among plural first drive electrodes.

Preferably, plural individual electrodes each of which includes the ink guide, the through hole, the first drive electrode and the second drive electrode are arranged in a two-dimensional manner along a first direction and a second direction perpendicular to the first direction, and first drive electrodes of the two or more individual electrodes are wired and connected to each other along the first direction and second drive electrodes of the two or more individual electrodes are wired and connected to each other along the second direction.

[0020]

Preferably, the electrostatic ink jet head further includes: a floating conduction plate that is provided to be common with respect to plural ejection electrodes, and arranged closer to a side of the head substrate than the ink flow path. Further, preferably, the ink jet head further includes: a guard electrode which is provided between adjacent ejection electrodes and suppresses electric field interferences occurring between the adjacent ejection electrodes. (Further, it is possible that the ink jet head further includes: a shield

electrode that is provided to be common with respect to plural ejection electrodes, and arranged closer to a side of the ink flow path than the ejection electrode.)

[0021]

In order to attain the second object described above, a third aspect of the present invention provides an electrostatic ink jet recording apparatus, characterized by including: the respective electrostatic ink jet heads described above; means for holding the recording medium; means for relatively moving the ink jet head and the recording medium; means for applying a predetermined bias voltage between the ejection electrode and the recording medium; and means for applying a predetermined ejection voltage to the ejection electrode in accordance with the image to be recorded on the recording medium.

[0022]

In order to attain the second object described above, a fourth aspect of the present invention provides an electrostatic ink jet recording method for recording an image on a recording medium, characterized by including: applying a predetermined bias voltage between the recording medium and the ejection electrode of the respective electrostatic ink jet heads described; moving the ink jet head relative to the recording medium; applying a predetermined ejection voltage to the ejection electrode in accordance with the image to be recorded on the recording medium; and ejecting the ink concentrated in a tip end portion of the ink guide of the ink jet head.

[0023]

[Embodiment of the Invention]

An electrostatic ink jet head according to the present invention, and a recording apparatus and a

recording method using the ink jet head will now be described in detail based on preferred embodiments with reference to the accompanying drawings.

[0024]

Fig. 1 is a schematic cross-sectional view showing an outlined construction of an embodiment of the electrostatic ink jet head according to the first and second aspects of the present invention.

An electrostatic ink jet head 10 shown in the figure is used for recording an image on a recording medium P in accordance with image data by ejecting ink Q containing charged fine particle component like pigments (toner, for instance) by means of an electrostatic force. For that purpose, the ink jet head 10 includes a head substrate 12, an ink guide 14, an insulating substrate 16, an ejection electrode 18, a counter electrode 20 supporting the recording medium P, charge unit 22 for charging the recording medium P, a signal voltage source 24, and a floating conduction plate 26.

[0025]

It should be noted here that in the example shown in Fig. 1, only one individual electrode serving as an ejection means constituting the ink jet head 10 is conceptually illustrated. The number of individual electrodes provided in the ink jet head 10 is not specifically limited so long as at least one individual electrode is provided. Also, no limitation is imposed on physical arrangement and the like of the individual electrodes. For instance, it is also possible to construct a line head by one-dimensionally or two-dimensionally arranging multiple individual electrodes. Also, the ink jet head to which the present invention is applied is applicable to both of monochrome recording and

color recording.

[0026]

In the ink jet head 10 of the illustrated example, the ink guide 14 is made of an insulating resin flat plate having a predetermined thickness and including a protrusion-like tip end portion 14a, and is arranged on the head substrate 12 for each individual electrode. Also, a through hole 28 is formed in the insulating substrate 16 at a position corresponding to a position at which the ink guide 14 is arranged. The ink guide 14 passes through the through hole 28 formed in the insulating substrate 16 and its tip end portion 14a protrudes upward from the upper surface of the insulating substrate 16 in the drawing, that is, from a surface thereof on the recording medium P side. Note that a slit serving as an ink guide groove that guides the ink Q into the tip end portion 14a by capillary action may be formed in a center portion of the ink guide 14 in a vertical direction in the drawing.

[0027]

It should be noted here that the tip end portion 14a side of the ink guide 14 is formed to gradually taper into a substantially triangular shape (or a substantially trapezoidal shape) toward the counter electrode 20 side. Here, it is preferable that a metal has been vapor-deposited on the tip end portion (extreme tip end portion) 14a of the ink guide 14 from which the ink Q is to be ejected. Although it is not always necessary to carry out the metal vapor-deposition for the tip end portion 14a of the ink guide 14, it is preferable that the metal vapor-deposition is conducted because the effective dielectric constant of the tip end portion 14a of the ink guide 14 becomes large as a result of

the metal vapor-deposition and an effect of easily generating a strong electric field is obtained. Also, the shape of the ink guide 14 is not specifically limited so long as it is possible to concentrate the ink Q, in particular, the charged fine particle component in the ink Q in the tip end portion 14a through the through hole 28 in the insulating substrate 16. For instance, the shape of the tip end portion 14a may be changed as appropriate into a shape other than the protrusion, such as a conventionally known shape disclosed in Patent Document 1 described above or the like.

[0028]

The head substrate 12 and the insulating substrate 16 are arranged so as to be spaced apart from each other by a predetermined distance and an ink flow path 30 functioning as an ink reservoir (ink chamber) for supplying the ink Q to the ink guide 14 is formed between the head substrate 12 and the insulating substrate 16. Note that the ink Q in the ink flow path 30 contains fine particle component charged to the same polarity as the voltage applied to the ejection electrode 18, and is circulated by a not-shown ink circulation mechanism in a predetermined direction (from the right to the left, in the illustrated example) in the ink flow path 30 at a predetermined speed (ink flow rate of 200 mm/s, for instance) at the time of recording. Hereinafter, a case where color particles in the ink are positively charged will be described as an example.

[0029]

Also, as shown in Fig. 2(a), the ejection electrode 18 is arranged in a ring shape, that is, as a circular electrode 18a for each individual electrode on the upper surface of the insulating substrate 16 in the drawing,

that is, on a surface thereof on a recording medium P side so as to surround the through hole 28 formed in the insulating substrate 16. The ejection electrode 18 is connected to the signal voltage source 24 that generates a pulse signal (predetermined pulse voltage, for example, 0 V at a low-voltage level and 400 to 600 V at a high-voltage level) corresponding to ejection data (ejection signal) such as image data or print data.

It should be noted here that the ejection electrode 18 is not limited to the ring-like circular electrode 18a shown in Fig. 2(a). That is, no specific limitation is imposed on the ejection electrode 18 so long as the electrode is a surrounding electrode arranged so as to surround the outer periphery of the ink guide 14 with a distance or side-by-side electrodes arranged at both sides of the ink guide 14 so as to oppose each other with a distance. In the case of the surrounding electrode, the ejection electrode 18 is preferably a substantially circular electrode, more preferably a circular electrode as shown in Fig. 2(a). On the other hand, in the case of the side-by-side electrodes, the ejection electrodes 18 are preferably substantially parallel electrodes, more preferably parallel electrodes 18b shown in Fig. 3(a). Note that as the side-by-side electrodes, parallel electrodes or substantially parallel electrodes shown in Figs. 3(c) and 3(d) to be described later may be used.

The following description will be made by taking the ring-like circular electrode 18a shown in Fig. 2(a) as a representative example of the surrounding electrode and taking the parallel electrode 18b shown in Fig. 3(a) and, Fig. 3(c) as a representative example of the side-by-side electrodes.

[0030]

The counter electrode 20 is arranged at a position opposing the tip end portion 14a of the ink guide 14 and includes an electrode substrate 20a and an insulation sheet 20b arranged on the lower surface of the electrode substrate 20a in the drawing, that is, on a surface thereof on the ink guide 14 side. The electrode substrate 20a is grounded. Also, the recording medium P is supported by the lower surface of the counter electrode 20 in the drawing, that is, on a surface thereof on the ink guide 14 side, in other words, on a surface of the insulation sheet 20b, and is electrostatically adsorbed on the surface. The counter electrode 20 (insulation sheet 20b) functions as a platen of the recording medium P.

Here, at least at the time of recording, the surface of the insulating sheet 20b of the counter electrode 20, that is, the recording medium P is charged by the charge unit 22 to a predetermined negative high voltage (-1.5 kV, for instance) having a polarity opposite to the high voltage (pulse voltage) applied to the ejection electrode 18. As a result of the negative charge by the charge unit 22, the recording medium P is constantly biased to the negative high voltage with respect to the ejection electrode 18 and is electrostatically adsorbed on the insulation sheet 20b of the counter electrode 20.

[0031]

Here, the charge unit 22 includes a scorotron charger 22a that charges the recording medium P to the negative high voltage and a bias voltage source 22b that supplies the negative high voltage to the scorotron charger 22a. Note that the charge means of the charge unit 22 used in the present invention is not limited to the scorotron charger 22a and it is also possible to use

various other discharge means such as a corotron charger, a solid charger, and a discharge needle.

It should be noted here that in the illustrated example, the counter electrode 20 includes the electrode substrate 20a and the insulation sheet 20b, and the recording medium P is charged to the negative high voltage by the charge unit 22 and is electrostatically adsorbed on the surface of the insulation sheet 20b. However, the present invention is not limited to this and the counter electrode 20 may be constructed only using the electrode substrate 20a. In this case, the counter electrode 20 (electrode substrate 20a itself) is connected to a negative high-voltage bias voltage source and is constantly biased to a negative high voltage, thereby having the recording medium P electrostatically adsorbed on the surface of the counter electrode 20.

Also, the electrostatic adsorption of the recording medium P on the counter electrode 20 and the charge of the recording medium P to the negative high voltage (or the application of the negative bias high voltage to the counter electrode 20) may be performed using different negative high-voltage sources. Further, the supporting of the recording medium P by the counter electrode 20 is not limited to the electrostatic adsorption of the recording medium P and another supporting method or supporting means may be used.

[0032]

The floating conduction plate 26 is arranged below the ink flow path 30 and is electrically insulated (in high-impedance state). In the illustrated example, the floating conduction plate 26 is arranged inside the head substrate 12, although the present invention is not limited to this and the position of the floating

conduction plate 26 may be changed so long as this plate 26 is arranged below the ink flow path 30. For instance, the floating conduction plate 26 may be arranged below the head substrate 12 or arranged inside the head substrate 12 on an upstream side of the ink flow path 30 with respect to the position of the individual electrode.

At the time of recording of an image, the floating conduction plate 26 generates an induced voltage in accordance with the value of a voltage applied to the individual electrode and causes the fine particle component in the ink Q in the ink flow path 30 to migrate to the insulating substrate 16 side and to be concentrated. Consequently, it is required that the floating conduction plate 26 is arranged on the head substrate 12 side with respect to the ink flow path 30. Also, it is preferable that the floating conduction plate 26 is arranged on an upstream side of the ink flow path 30 with respect to the position of the individual electrode. With this floating conduction plate 26, the concentration of the charged fine particle component in an upper layer in the ink flow path 30 is increased. As a result, it becomes possible to increase the concentration of the charged fine particle component in the ink Q passing through the through hole 28 of the insulating substrate 16 to a predetermined level, to cause the charged fine particle component to be concentrated in the tip end portion 14a of the ink guide 14, and to maintain the concentration of the charged fine particle component in the ink Q ejected as an ink droplet R at a predetermined level.

Also, the induced voltage generated by the floating conduction plate changes in accordance with the number of operating channels, so that even if a voltage to the

floating conduction plate is not controlled, charged particles required for ejection is supplied, which makes it possible to prevent clogging. Note that a power source may be connected to the floating conduction plate and a predetermined voltage may be applied thereto.

[0033]

Next, another embodiment of the electrostatic ink jet head in which side-by-side electrodes represented by parallel electrodes are used, will be described with reference to Figs. 3(c) and 3(d).

An electrostatic ink jet head 32 shown in Figs. 3(c) and 3(d) includes insulating supporting substrates 33a and 33b arranged so as to oppose each other with a predetermined distance, parallel electrodes 34a and 34b that are respectively supported on the inner surfaces of the insulating supporting substrates 33a and 33b, partition walls 35a and 35b arranged on both sides in a direction orthogonal to the direction in which the insulating supporting substrates 33a and 33b oppose each other, an ink guide 36 supported by the partition walls 35a and 35b and arranged in parallel between the parallel electrodes 34a and 34b, outer wall plates 37a and 37b respectively arranged so as to be spaced apart from the outer surfaces of the insulating supporting substrates 33a and 33b by a predetermined distance, and an ink flow path 38 including an ink supply path 38a formed between the partition walls 35a and 35b, the parallel electrodes 34a and 34b, and the insulating supporting substrates 33a and 33b and ink recovery paths 38b and 38c formed between the insulating supporting substrates 33a and 33b and the outer wall plates 37a and 37b.

[0034]

End surfaces (lower end surfaces in the drawing) of

the insulating supporting substrates 33a and 33b on one side are connected to an insulating supporting substrate 33c and end surfaces (upper end surfaces in the drawing) thereof on the other side are opened. Accordingly, an end surface (lower end surface in the drawing) of the ink supply path 38a on one side is closed by the insulating supporting substrate 33c and a supply port 38d communicating with an external ink circulation path is arranged in proximity to the closed end. Also, end surfaces (lower end surfaces in the drawing) of the outer wall plates 37a and 37b on one side are connected to an external wall plate 37c and are closed, and end surfaces (upper end surfaces in the drawing) thereof on the other side are opened. Accordingly, the ink recovery paths 38b and 38c communicate with an ink recovery path 38e formed between the insulating supporting substrate 33c and the outer wall plate 37c, and the ink recovery path 38e is connected to a recovery port 38f communicating with an external ink circulation path.

[0035]

The ink guide 36 divides the ink supply path 38a into two portions and is made of an insulating resin flat plate or film having a predetermined thickness and including a protrusion-like tip end portion 36a protruding from the opened ends of the insulating supporting substrates 33a and 33b, that is, from the opened ends of the parallel electrodes 34a and 34b, in other words, from the opened end of the ink supply path 38a. Also, both sides of ink guide 36 are supported by the partition walls 35a and 35b. Like the tip end portion 14a of the ink guide 14 shown in Fig. 3(a), the tip end portion 36a of the ink guide 36 gradually tapers into a substantially triangular shape (or a substantially

trapezoidal shape) toward a not-shown recording medium side.

[0036]

After being supplied to the ink supply path 38a from the external ink circulation path through the supply port 38d, the ink moves toward the opened ends by capillary action or the like in the ink supply path 38a divided into two portions by the ink guide 36, and moves upward along the ink guide 36 in the drawing. A part of the ink moved upward aggregates in the tip end portion 36a of the ink guide 36 and the charged fine particle component in the ink is concentrated. On the other hand, the remaining ink overflows from the insulating supporting substrates 33a and 33b, and flows into the ink recovery paths 38b and 38c, and two streams merge with each other in the ink recovery path 38e, and the ink is recovered to the external ink circulation path through the recovery port 38f.

The ink in the tip end portion 36a of the ink guide 36, in which the charged fine particle component is concentrated, is caused to fly toward the not-shown recording medium as an ink droplet through application of predetermined pulse voltages to the parallel electrodes 34a and 34b.

[0037]

By the way, in the present invention, when the ejection electrode 18 is a surrounding electrode represented by the ring-like circular electrode 18a shown in Fig. 2(a), it is required that, as shown in Fig. 2(b), a ratio (Da:H) between an inside diameter Da of the surrounding electrode (circular electrode) 18a and a distance from the ejection electrode (surrounding electrode) 18 to the tip end of the ink guide 14

protruding on the recording medium P side, that is, a distance H from the surface of the circular electrode 18a to the tip end portion 14a of the ink guide 14 is set in a range of 1:0.5 to 1:2, preferably in a range of 1:0.7 to 1:1.7. Here, in the case of a surrounding electrode, such as a substantially circular electrode whose inside diameter is not constant, an effective inside diameter (such as an average inside diameter) that can be regarded as a substantial inside diameter need only be used as the inside diameter Da.

[0038]

Also, in the present invention, when the side-by-side electrodes represented by the parallel electrodes 18a shown in Fig. 3(a) or the parallel electrodes 34a and 34b shown in Figs. 3(c) and 3(d) are used as the ejection electrode 18, it is required that, as shown in Fig. 3(b) or 3(c), a ratio (Ds:H) between a distance Ds between the parallel electrodes 18a or a distance Ds between the parallel electrodes 34a and 34b and a distance from the ejection electrode (side-by-side electrodes) 18 to the tip end of the ink guide 14 protruding on the recording medium P side, that is, a distance H from the surface of the parallel electrodes 18b or from the opened end surfaces of the parallel electrodes 34a and 34b to the tip end portion 14a of the ink guide 14 is set in a range of 1:0.7 to 1:2.8, preferably in a range of 1:1.0 to 1:2.4. Here, in the case of side-by-side electrodes, such as substantially parallel electrodes with a distance therebetween that is not constant, an effective distance (such as an average distance) that can be regarded as a substantial distance need only be used as the distance Ds.

[0039]

Here, in the present invention, the inventor of the

present invention measured an electric field strength (V/m) at an ejection portion, that is, at the tip end portion 14a of the ink guide 14 by changing the distance H between the surface of the ejection electrode 18 and the tip end portion 14a of the ink guide 14, that is, a protrusion amount (hereinafter referred to as the "projection amount") H of the tip end portion 14a of the ink guide 14 using a real model shown in Fig. 4 where the ink guide 14 is mounted on the floating conduction plate 26, the ejection electrode 18 is arranged around the ink guide 14, and the counter electrode 20 is arranged so as to oppose the tip end portion 14a of the ink guide 14. Also, the distance between the floating conduction plate 26 and the ejection electrode 18 and the distance between the ejection electrode 18 and the counter electrode 20 are both set at 500 μm, the floating conduction plate 26 comes into an insulation state (high-impedance state), the counter electrode 20 is applied with a negative high voltage of -1500 V as a bias voltage, and the ejection electrode 18 is applied with an ejection voltage of +400 V. Further, a circular electrode 18a having an inside diameter (Da) of 200 μm is used as the electrode structure of the ejection electrode 18 and the projection amount H is changed from 75 μm to 250 μm. Note that the application of the negative bias high voltage of -1500 V to the counter electrode 20 is the equivalent of the negative high voltage charge to -1500 V of the recording medium P electrostatically adsorbed on the counter electrode 20.

[0040]

Results of this measurement are shown in Fig. 5.

Here, although not illustrated, the ink guide 14 is produced using ceramic (dielectric constant ε=20) so as

to have a tip end angle of 45° and a thickness of 75 μm. The horizontal axis in Fig. 5 represents a distance from the center of the tip end portion 14a of the ink guide 14 along sloped lines indicated by arrows c shown in Fig. 4.

It can be seen from Fig. 5 that when the projection amount H of the ink guide 14 is set at 200 μm, the electric field strength exceeds $2.5 \times 10^{+7}$ V/m and becomes maximum. That is, it can be seen from Fig. 5 that it is possible to obtain an optimum projection amount H of the ink guide 14 by changing the projection amount H while setting the inside diameter of the circular electrode 18a constant. In the case of the circular electrode 18a, when the ratio between the projection amount H and the inside diameter Da is set at around 1.0, the electric field strength becomes maximum.

This result indicates that in the case of the circular electrode 18a shown in Fig. 4, if the electric field strength, with which it is possible to perform ink ejection with reliability and stability, is equal to or lower than the maximum electric field strength shown in Fig. 5, it is possible to reduce an application voltage to the circular electrode 18a.

[0041]

Therefore, the inventor of the present invention obtained a pulse voltage (lowest ejection voltage) required to perform ink ejection with reliability and stability for each predetermined projection amount H by changing the pulse voltage (ejection voltage) applied to the circular electrode 18a using the same condition as in the case of Fig. 5 except that a circular electrode 18a having an inside diameter of 150 μm is used as the ejection electrode 18 and the projection amount H is changed from 50 μm to 330 μm in the ejection structure

(individual electrode structure) shown in Fig. 4.

[0042]

Results of this experiment are shown in Fig. 6(a).

It can be seen from Fig. 6(a) that when the ratio (H/Da) between the distance (projection amount) H to the ejection portion and the circular ejection electrode inside diameter Da is set at 1.0, even if a metallic film or the like is not formed for the tip end portion 14a of the ink guide 14, the required pulse voltage is minimized to 400 V. This required pulse voltage is increased when the ratio (H/Da) is decreased or increased from 1.0.

By the way, in the present invention, the ratio (H/Da) between the distance H to the ejection portion and the circular ejection electrode inside diameter Da is set in a range of 0.5 to 2. This is because in the electrostatic ink jet head, when consideration is given to a withstand voltage and the like of a semiconductor device such as an IC constituting a drive circuit that drives each individual electrode, safety, the individual electrode structure, current consumption, and the like, the upper limit of the pulse voltage applicable to the ejection electrode 18 becomes around 600 V. As can be seen from Fig. 6(a), unless the voltage value falls within the limited range described above, the required pulse voltage exceeds 600 V. Note that it is preferable that the ratio (H/Da) is set in a range of 0.7 to 1.7. In this case, it becomes possible to further reduce the pulse voltage applied to the ejection electrode 18 to 500 V.

[0043]

Also, results obtained by using the parallel electrodes 18b as the ejection electrode 18 in place of the circular electrode 18a are shown in Fig. 6(b).

It can be seen from Fig. 6(b) that when the ratio (H/Ds) between the distance (projection amount) H to the ejection portion and the parallel ejection electrode distance Ds is set at 1.4, even if a metallic film or the like is not formed for the tip end portion 14a of the ink guide 14, the required pulse voltage is minimized to 450 V. This required pulse voltage is increased when the ratio (H/Ds) is decreased or increased.

By the way, in the present invention, the ratio (H/Ds) between the distance H to the ejection portion and the parallel ejection electrode distance Ds is set in a range of 0.7 to 2.8. This is because in the electrostatic ink jet head, when consideration is given to a withstand voltage and the like of a semiconductor device such as an IC constituting a drive circuit that drives each individual electrode, safety, the individual electrode structure, current consumption, and the like, the upper limit of the pulse voltage applicable to the ejection voltage 18 becomes around 600 V. As can be seen from Fig. 6(b), when the limit range described above is exceeded, the required pulse voltage exceeds 600 V. Note that it is preferable that the ratio (H/Ds) is set in a range of 1.0 to 2.4. In this case, it becomes possible to further reduce the pulse voltage applied to the ejection electrode 18 to 500 V.

As described above, in the present invention, the ratio between the distance to the ejection portion and the circular ejection electrode inside diameter or the parallel ejection electrode distance is set in the appropriate range described above. As a result, it becomes possible to achieve a reduction in the ejection voltage, to widen the choice of ink guide materials (low dielectric constant material becomes usable, for

instance), and to widen the choice of ink guide tip end structures.

[0044]

The electrostatic ink jet head according to the present invention is basically constructed in the manner described above. Next, an operation of the ink jet head of the present invention will be described by taking, as a representative example, an operation of the electrostatic ink jet head 10 shown in Fig. 1.

In the electrostatic ink jet head 10 shown in Fig. 1, at the time of recording, the ink Q containing the fine particle component charged to the same polarity as that of the voltage applied to the ejection electrode 18 (positive (+), for instance) is circulated by a not-shown ink circulation mechanism including a pump and the like in the ink flow path 30 in a direction of an arrow "a" in Fig. 1, that is, in a direction from the right to the left. When doing so, the recording medium P electrostatically adsorbed on the counter electrode 20 is charged to a reversed polarity, that is, to a negative high voltage (-1500 V, for instance). Also, the floating conduction plate 26 comes into an insulation state (high-impedance state).

[0045]

Here, when no pulse voltage is applied to the ejection electrode 18 or when the pulse voltage applied to the ejection electrode 18 is set at a low voltage level (0 V), a voltage (potential difference) between the ejection electrode 18 and the counter electrode 20 (recording medium P) becomes equal to a bias voltage (1500 V, for instance) and the electric field strength in proximity to the tip end portion 14a of the ink guide 14 becomes low. Consequently, the ink Q will not fly out

from the tip end portion 14a of the ink guide 14, that is, will not be ejected as the ink droplet R. Under this state, however, a part of the ink Q in the ink flow path 30, in particular, the charged fine particle component contained in the ink Q moves upward in a direction of an arrow "b" in Fig. 1, that is, in a direction from the lower side of the insulating substrate 16 to the upper side thereof while passing through the through hole 28 in the insulating substrate 16 by migration action, capillary action, or the like and is supplied to the tip end portion 14a of the ink guide 14.

[0046]

On the other hand, when a pulse voltage at a high voltage level (400 to 600 V, for instance) is applied to the ejection electrode 18, a voltage (400 to 600 V, for instance) that is equal to the applied pulse voltage is superimposed on the bias voltage (1500 V, for instance). Therefore, the voltage (potential difference) between the ejection electrode 18 and the counter electrode 20 (recording medium P) is increased and becomes 1900 V to 2100 V, and the electric field strength in proximity to the tip end portion 14a of the ink guide 14 is also increased. Under this state, the ink Q moved upward along the ink guide 14 to the tip end portion 14a above the insulating substrate 16, in particular, the charged fine particle component concentrated in the ink Q flies out from the tip end portion 14a of the ink guide 14 as the ink droplet R containing the charged fine particle component by means of an electrostatic force, is attracted by the counter electrode 20 (recording medium P) biased to the negative high voltage (-1500 V, for instance), and adheres on the recording medium P.

[0047]

Here, in the present invention, the ratio (H/Da) between the projection amount H of the tip end portion 14a of the ink guide 14 and the inside diameter Da of the ejection electrode 18 (circular electrode 18a) is set in the appropriate range of 0.5 to 2. Also, the ratio (H/Ds) between the projection amount H and the distance Ds between the ejection electrodes 18 (parallel electrodes 18b) is set in the appropriate range of 0.7 to 2.8. Therefore, it becomes possible to achieve reliable and stabilized ink ejection even if the pulse voltage applied to the ejection electrode 18 is reduced to around 600 V or lower.

By ejecting the ink in this manner in accordance with image data and forming dots on the recording medium P while relatively moving the ink jet head 10 and the recording medium P supported on the counter electrode 20, an image corresponding to the image data can be recorded on the recording medium P.

[0048]

It should be noted here that in the electrostatic ink jet head 10 described above, the ejection electrode 18, such as the circular electrode 18a or the parallel electrodes 18b, forming a single-layered electrode structure is arranged on the upper surface of the insulating substrate 16 in the drawing. However, the present invention is not limited to this and a two-layered electrode structure may be adopted in which ejection electrodes 18 are arranged on the upper surface and the lower surface of the insulating substrate 16.

Fig. 7(a) shows the outline of an electrostatic ink jet head 40 according to another embodiment of the present invention where a two-layered electrode structure is formed by ejection electrodes.

The ink jet head 40 shown in Fig. 7(a) has the same construction as the ink jet head 10 shown in Fig. 2(a) except that a second drive electrode 42 is provided on the lower surface of an insulating substrate 16 in the drawing. Therefore, the same construction elements are given the same reference numerals and are not described in this embodiment. That is, differences will be mainly described in this embodiment.

[0049]

In the ink jet head 40 shown in Fig. 7(a), an ejection electrode 18 has a two-layered electrode structure where a circular electrode (hereinafter referred to as the "first drive electrode") 18a is arranged on the upper surface of the insulating substrate 16 in the drawing and the second drive electrode 42 is arranged on the lower surface of the insulating substrate 16. Here, the first drive electrode 18a is provided in a ring shape for each individual electrode on the upper surface of the insulating substrate 16 so as to surround a through hole 28 formed in the insulating substrate 16. On the other hand, the second drive electrode 42 is provided in a sheet manner so as to be common among all individual electrodes on the lower surface of the insulating substrate 16 except for each region in which the through hole 28 is formed in the insulating substrate 16. Also, the second drive electrode 42 is constantly biased to a high voltage at the time of recording.

[0050]

When the ink jet head 40 includes 15 individual electrodes as shown in Fig. 7(b), for instance, there are formed three rows of the individual electrodes, with each row including five individual electrodes. In the ink jet head 40, ink ejection/non-ejection is controlled by the

first and second drive electrodes 18a and 42. Note that the ink jet head 40 of this embodiment uses the two-layered electrode structure formed by the first and second drive electrodes 18a and 42, although the present invention is not limited to this and there may be used any other electrode structure having two or more layers of drive electrodes.

[0051]

Next, there will be described arrangement of the first and second drive electrodes 18a and 42. The first drive electrode 18a needs to be arranged closer to the insulating substrate 16 side than the ink flow path 30. On the other hand, the second drive electrode 42 needs to be arranged closer to the head substrate 12 side than the first drive electrode 18a. When the first drive electrode 18a is arranged on the upper surface of the insulating substrate 16 in the drawing, for instance, the second drive electrode 42 may be arranged on the lower surface of the insulating substrate 16 or inside the head substrate 12. When the second drive electrode 42 is arranged inside the head substrate 12, it is preferable that a floating conduction plate 26 is arranged inside the head substrate 12 on an upstream side of an ink flow path 30.

[0052]

In the ink jet head 40 of this embodiment including the ejection electrode 18 having the two-layered electrode structure described above, the second drive electrode 42 is constantly biased to a predetermined positive voltage (600 V, for instance) and the first drive electrode 18a is switched between a ground state and a high-impedance state in accordance with image data, for instance. As a result, ejection/non-ejection of the

ink Q (ink droplet R) containing the fine particle component, such as pigments, charged to the same polarity as the high-voltage level applied to the second drive electrode 42 can be controlled. That is, in the ejection head 40, when the first drive electrode 18a is set under the ground state, the electric field strength in proximity to the tip end portion 14a of the ink guide 14 remains low and the ink Q will not fly out from the tip end portion 14a of the ink guide 14. On the other hand, when the first drive electrode 18a is set under the high-impedance state, the electric field strength in proximity to the tip end portion 14a of the ink guide 14 is increased and the ink Q concentrated in the tip end portion 14a of the ink guide 14 flies out from the tip end portion 14a by means of an electrostatic force. When doing so, it is also possible to further concentrate the ink Q by selecting the condition.

[0053]

In this case, the ratio between the inside diameter (Da) of the first drive electrode 18a and the projection amount (H) of the ink guide 14 is set so as to fall within the aforementioned appropriate limit range of the present invention, so that even if the bias voltage applied to the second drive electrode 42 is reduced to around 600 V or lower, it is possible to achieve reliable and stabilized ink ejection. Note that the ratio between the projection amount (H) of the ink guide 14 and the inside diameter of the through hole of the second drive electrode 42 may also be set so as to fall within the appropriate limit range of the present invention.

With the construction of this embodiment, switching to a high voltage is not performed at the time of image recording, so that no large electric power is consumed

for the switching. Consequently, even in the case of an ink jet head that is required to perform high-definition recording at a high speed, it becomes possible to significantly reduce power consumption. Also, even when the individual electrodes and drive circuits are implemented at a physically extremely high density, there is hardly any risk of discharge. As a result, there is provided an advantage that it is possible to cope with both high-density implementation and high-voltage driving with safety.

[0054]

It should be noted here that in the electrostatic ink jet head 40 described above, the sheet-like second drive electrode 42 that is common among all individual electrodes is used. However, the present invention is not limited to this and a circular electrode may be provided as the second drive electrode for each individual electrode.

Further, when the first drive electrode and the second drive electrode of each individual electrode are each a circular electrode, a control method may be used with which a pulse voltage applied to the first drive electrode is also applied to the second drive electrode. In this case, an electric line of force from the first drive electrode and an electric line of force from the second drive electrode are added to each other and the electric field strength in the tip end portion of the ink guide is increased, so that it becomes possible to reduce the value of the pulse voltage applied to each drive electrode as compared with the case of the single-layered drive electrode.

[0055]

Fig. 8(a) shows the outline of an ink jet head 41

according to still another preferred embodiment of the present invention which includes ejection electrodes of another two-layered electrode structure.

The ink jet head 41 shown in Fig. 8(a) has the same construction as the ink jet head 40 shown in Fig. 7(a) except that a second drive electrode 44 that is a circular electrode is provided for each individual electrode on the lower surface of the insulating substrate 16 in the drawing in place of the sheet-like second drive electrode 42 that is common among all individual electrodes. Therefore, the same construction elements are given the same reference numerals and the description thereof is omitted in this embodiment. That is, differences will be mainly described in this embodiment.

[0056]

In the ink jet head 41 shown in Fig. 8(a), an ejection electrode 18 has a two-layered electrode structure where a first drive electrode 18a that is a circular electrode is arranged on the upper surface of an insulating substrate 16 in the drawing and the second drive electrode 44 that is also a circular electrode is arranged on the lower surface of the insulating substrate 16. Here, the first drive electrode 18a is provided in a ring shape for each individual electrode so as to surround a through hole 28 formed in the insulating substrate 16, with multiple first drive electrodes 18a being connected to each other in a row direction (main scanning direction) as shown in Fig. 8(b). Also, the second drive electrode 44 is provided in a ring shape for each individual electrode so as to surround the through hole 28 formed in the insulating substrate 16, with multiple second drive electrodes 44 being connected

to each other in a column direction (sub-scanning direction) as shown in Fig. 8(b).

[0057]

In this embodiment, at the time of recording, only one first drive electrode 18a is set at a high-voltage level or under a high-impedance state (ON state) and all of the other first drive electrodes 18a are driven to a ground level (ground state: OFF state). Also, all second drive electrodes 44 are driven to a high-voltage level or a ground level in accordance with the image data. Note that as a modification, the first and second drive electrodes 18a and 44 may be driven in a reversed manner.

[0058]

As described above, the first and second drive electrodes 18a and 44 are arranged in a matrix manner so as to form the two-layered electrode structure. By the first and second drive electrodes 18a and 44, ink ejection/non-ejection at respective individual electrodes is controlled. That is, when the first drive electrodes 18a are set at the high-voltage level or under a floating state and the second drive electrodes 44 are set at the high-voltage level, the ink will be ejected. When one of the first drive electrodes 18a and the second drive electrodes 44 are set at the ground level, the ink will not be ejected.

[0059]

Fig. 8(b) is a conceptual diagram showing an exemplary arrangement of the first and second drive electrodes 18a and 44. As shown in this drawing, when the ink jet head 41 includes 15 individual electrodes, for instance, five individual electrodes (1, 2, 3, 4, and 5) are arranged on each row in the main scanning direction and three individual electrodes (A, B, and C)

are arranged on each column in the sub-scanning direction. At the time of recording, the five first drive electrodes 18a arranged on the same row are simultaneously driven to the same voltage level. In the same manner, the three second drive electrodes 44 arranged on the same column are simultaneously driven to the same voltage level.

[0060]

Accordingly, in the electrostatic ink jet head 41 of this embodiment, it is possible to arrange plural individual electrodes in a two-dimensional manner with respect to the row direction and the column direction.

In the case of the ink jet head shown in Fig. 8(b), for instance, the five individual electrodes (first drive electrodes 18a) on the row A are arranged at predetermined intervals with respect to the row direction. The same applies to the row B and the row C. Also, the five individual electrodes on the row B are spaced apart from the row A by a predetermined distance in the column direction and are respectively arranged between the five individual electrodes on the row A and the five individual electrodes on the row C with respect to the row direction. In the same manner, the five individual electrodes on the row C are spaced apart from the row B by a predetermined distance in the column direction and are respectively arranged between the five drive electrodes on the row B and the five drive electrodes on the row A with respect to the row direction.

[0061]

In this manner, the individual electrodes (first drive electrodes 18a) on each row are arranged so as to be displaced from the individual electrodes on other rows in the row direction. With this arrangement, one line to be recorded on the recording medium P is divided into

three groups in the row direction.

That is, one line to be recorded on the recording medium P is divided into multiple groups, whose number is equal to the number of rows of the first drive electrodes 18a with respect to the row direction and sequential recording is performed in a time-division manner. In the case of the example shown in Fig. 8(b), for instance, sequential recording is performed for the rows A, B, and C of the first drive electrodes 18a, thereby recording one line of an image on the recording medium P. In this case, as described above, one line to be recorded on the recording medium P is divided into three groups in the row direction and sequential recording is performed in a time-division manner.

[0062]

Accordingly, in a matrix drive system adopted in this embodiment, division-recording is performed with respect to the row direction, so that the recording speed is lowered in accordance with an increase in the number of rows of the first drive electrodes 18a. However, it becomes possible to reduce the number of drivers of a drive circuit, which provides an advantage that it is possible to reduce an implementation area. Also, in this embodiment, it is also possible to appropriately determine the recording speed and the number of drivers as necessary, so that there is provided an advantage that it is possible to obtain a recording speed and an implementation area of the drive circuit that are optimum for the system.

It should be noted here that in the ink jet head 41 of this embodiment, there is used the two-layered electrode structure formed by the first and second drive

electrodes 18a and 44. However, the present invention is not limited to this and there may be used any other electrode structure having two or more layers of drive electrodes.

[0063]

In the ink jet head 41 of this embodiment having the ejection electrodes of the two-layered electrode structure described above, the second drive electrodes 44 constantly receive application of a predetermined voltage (600 V, for instance) and the first drive electrodes 18a are switched between a ground state and a high-impedance state in accordance with image data, for instance. As a result, ejection/non-ejection of the ink Q (ink droplet R) containing the fine particle component such as pigments charged to the same polarity as the high-voltage level applied to the second drive electrodes 42 can be controlled. That is, in the ink jet head 41, when the first drive electrode 18a is set under the ground state, the electric field strength in proximity to the tip end portion 14a of the ink guide 14 becomes low and the ink Q will not fly out from the tip end portion 14a of the ink guide 14. On the other hand, when the first drive electrode 18a is set under the high-impedance state, the electric field strength in proximity to the tip end portion 14a of the ink guide 14 is increased and the ink Q concentrated in the tip end portion 14a of the ink guide 14 flies out from the tip end portion 14a by means of an electrostatic force.

[0064]

It should be noted here that an operation for switching the first drive electrode 18a between the ground level and the high voltage level in accordance with image data is performed in substantially the

same manner. As described above, in the ink jet head 41 of this embodiment, when one of the first drive electrodes 18a and the second drive electrodes 44 are set at the ground level, the ink will not be ejected and only when the first drive electrodes 18a are set under the high-impedance state or at the high-voltage level and the second drive electrodes 44 are set at the high-voltage level, the ink will be ejected.

That is, in the ink jet head 41 of this embodiment, it is important that clearly different two states of the electric field strength are obtained at the time of ejection and non-ejection of the ink. Accordingly, related parameters, such as arrangement (positional relationship) of the first and second drive electrodes 18a and 44, the levels of the high voltages applied to the first and second drive electrodes 18a and 44, the bias voltage of the counter electrode 20 (or the charge voltage of the recording medium), the thickness of the insulating substrate 16, and the shape of the ink guide 14, need only be determined as appropriate.

[0065]

In this embodiment, like in the preferred embodiments described above, the ratio between the inside diameter (Da) of the first drive electrodes 18a and the projection amount (H) of the ink guide 14 is set so as to fall within the aforementioned appropriate limit range of the present invention, so that even if the bias voltage applied to the second drive electrodes 44 is reduced to around 600 V or lower, it is possible to achieve reliable and stabilized ink ejection. Note that the ratio between the projection amount (H) of the ink guide 14 and the inside diameter of the second drive electrodes 44 may also be set so as to fall within the appropriate limit

range of the present invention.

With the construction of this embodiment, no large electric power is consumed for switching because it is possible to switch the first drive electrodes between the high-impedance state and the ground level. Therefore, according to this embodiment, it becomes possible to significantly reduce power consumption even in the case of an ink jet head that is required to perform high-definition recording at a high speed.

[0066]

Also, according to this embodiment, the individual electrodes are arranged in a two-dimensional manner and are matrix-driven, so that it becomes possible to significantly reduce the number of row drivers for driving multiple individual electrodes in the row direction and the number of column drivers for driving multiple individual electrodes in the column direction. Consequently, according to this embodiment, it becomes possible to significantly reduce the implementation area and power consumption of a circuit for driving the two-dimensionally arranged individual electrodes. In addition, according to this embodiment, it is possible to arrange the individual electrodes while maintaining relatively large margins therebetween, so that it becomes possible to significantly reduce a risk of discharge between the individual electrodes and to cope with both of high-density implementation and high-voltage driving with safety.

[0067]

It should be noted here that in the case of an electrostatic ink jet head, such as the ink jet heads 40 and 41 described above, that uses ejection electrodes having a two-layered electrode structure formed by the

first and second drive electrodes 18a and 42 or 44, when the individual electrodes are arranged at a high density, an electric field interference may occur between adjacent individual electrodes. Therefore, it is preferable that a guard electrode is provided between the first drive electrodes of adjacent individual electrodes and the electric lines of force to adjacent ink guides 14 are shielded by the guard electrode. The guard electrode is effective not only for the two-layered electrode structure but also for the single-layered structure described above.

[0068]

An outlined construction of an electrostatic ink jet head 50 that is still another preferred embodiment of the present invention, in which the guard electrode described above is provided for ejection electrodes forming a two-layered electrode structure, will be described with reference to Figs. 9, 10(a), and 10(b). Fig. 9 is a schematic perspective view of an example of the ink jet head of this embodiment, Fig. 10(a) is a schematic cross-sectional view of the ink jet head shown in Fig. 9, and Fig. 10(b) is the arrow view taken along the line VII-VII of Fig. 10(a).

The ink jet head 50 shown in Figs. 9, 10(a), and 10(b) has the same construction as the ink jet head 41 shown in Fig. 8(a) except that an insulation layer 56a is provided below second drive electrodes 44 arranged on the lower surface of an insulating substrate 16 in the drawings, an insulating layer 56b is provided above first drive electrodes 18a arranged on the upper surface of the insulating substrate 16 in the drawings, and a guard electrode 54 and an insulation layer 56c are provided on the insulating layer 56b in this order. Therefore, the

same construction elements are given the same reference numerals and the description thereof is omitted in this embodiment. That is, differences will be mainly described in this embodiment.

[0069]

In the ink jet head 50 shown in Figs. 9, 10(a), and 10(b), in addition to ejection electrodes 18 forming the two-layered structure including the first drive electrodes 18a that are each a circular electrode arranged on the upper surface of the insulating substrate 16 in the drawings in a ring shape for each individual electrode so as to surround a through hole 58 formed in the insulating substrate 16 and the second drive electrodes 44 that are each a circular electrode arranged on the lower surface of the insulating substrate 16 in the drawings in a ring shape for each individual electrode so as to surround the through hole 58 formed in the insulating substrate 16, there are provided the insulation layer 56a covering the lower side (lower surface) of the second drive electrodes 44, the sheet-like guard electrode 54 arranged above the first drive electrodes 18a with the insulation layer 56b in-between, and the insulation layer 56c covering the upper surface of the guard electrode 54. Here, the multiple first drive electrodes 18a are connected to each other in a row direction (main scanning direction) and the multiple second drive electrodes 44 are connected to each other in a column direction (sub-scanning direction).

[0070]

The through holes 58 are formed so as to also pass through the insulation layer 56a below the insulating substrate 16 and the insulation layers 56b and 56c above the insulating substrate 16. That is, the through holes

58 are formed so as to pass through a layered product of the insulation layer 56a, the insulating substrate 16, and the insulation layers 56b and 56c. Ink guides 14 are inserted into the through holes 58 from an insulation layer 56a side so that tip end portions 14a of the ink guides 14 protrude from the insulation layer 56c. Note that in the illustrated example, no ink guide groove is formed in the tip end portions 14a of the ink guides 14, but ink guide grooves may be formed in order to promote concentration of the ink Q and the charged fine particle component in the ink Q to the tip end portions 14a.

Here, the ratio between the protrusion amount (projection amount) H of the tip end portions 14a of the ink guides 14 from the first drive electrodes 18a and the inside diameter (Da) of the first drive electrodes 18a exposed to the through holes 58 is set in the range of 0.5 to 2, preferably in the range of 0.7 to 1.7. Note that it is preferable that the ratio between the projection amount H of the ink guides 14 and the inside diameter (Da) of the second drive electrodes 44 is also set so as to satisfy the condition described above.

[0071]

In this embodiment, the guard electrode 54 is arranged between the first drive electrodes 18a of adjacent individual electrodes and suppresses electric field interferences occurring between the ink guides 14 serving as ejection portions of the adjacent individual electrodes. As shown in Fig. 11(a), the guard electrode 54 is a sheet-like electrode, such as a metal plate, that is common among all individual electrodes, and holes are formed in the guard electrode 54 in portions corresponding to the first drive electrodes 18a formed around the through holes 58 for respective individual

electrodes two-dimensionally arranged (see Figs. 10(a) and 10(b)). Note that in this embodiment, the reason why the guard electrode 54 is provided is that if the individual electrodes are arranged at a high density, there is a case where an electric field generated by an individual electrode is influenced by the states of electric fields generated by its adjacent individual electrodes and therefore dot sizes and dot drawing positions fluctuate and recording quality is adversely affected.

[0072]

By the way, the upper side of the guard electrode 54 in the drawings is covered with the insulation layer 56c except for the through holes 58 and the insulation layer 56b is disposed between the guard electrode 54 and the first drive electrodes 18a, thereby insulating the electrodes 54 and 18a from each other. That is, the guard electrode 54 is arranged between the insulation layer 56c and the insulation layer 56b and the first drive electrodes 18a are arranged between the insulation layer 56b and the insulating substrate 16.

That is, as shown in Fig. 11(b), on the upper surface of the insulating substrate 16, that is, between the insulation layer 56b and the insulating substrate 16 (see Fig. 10), the first drive electrodes 18a formed around the through holes 58 for the respective individual electrodes are two-dimensionally arranged and the multiple first drive electrodes 18a are connected to each other in the column direction.

[0073]

Also, as shown in Fig. 11(c), on the upper surface of the insulation layer 56a (that is, on the lower surface of the insulating substrate 16), that is, between

the insulation layer 56a and the insulating substrate 16 (see Fig. 10), the second drive electrodes 44 formed around the through holes 58 for the respective individual electrodes are two-dimensionally arranged and multiple second drive electrodes 44 are connected to each other in the row direction.

Further, in this embodiment, in order to shield a repulsive electric field from the ejection electrode (drive electrode) 18 of each individual electrode (from the first and second drive electrodes 18a and 44, for instance) toward the ink flow path 30, a shield electrode may be provided on a flow path side with respect to the first and second drive electrodes 18a and 44.

[0074]

In this embodiment, like in the case of the embodiment shown in Fig. 8, at the time of recording, only one first drive electrode 18a is set at a high-voltage level or under a high-impedance state (ON state) and all other first drive electrodes 18a are driven to a ground level (ground state: OFF state). On the other hand, all second drive electrodes 44 are driven to a high-voltage level or a ground level in accordance with image data. Note that as another embodiment, the first and second drive electrodes 18a and 44 may be driven in a reversed manner.

[0075]

As described above, the first and second drive electrodes 18a and 44 are arranged in a matrix manner so as to form a two-layered electrode structure. By the first and second drive electrodes 18a and 44, ink ejection/non-ejection at respective individual electrodes is controlled. That is, when the first drive electrodes

18a are set at the high-voltage level or under a floating state and the second drive electrodes 44 are set at the high-voltage level, the ink will be ejected. When one of the first drive electrodes 18a and the second drive electrodes 44 are set at the ground level, the ink will not be ejected.

[0076]

It should be noted here that in this embodiment, pulse voltages may be applied to the first and second drive electrodes 18a and 44 in accordance with image signals and the ink ejection may be performed when both of these electrodes are set at the high-voltage level.

For instance, in an ink jet head 50 shown in Fig. 12, when a fine particle component in the ink Q is positively (+) charged, that is, when the ink Q contains positively charged particles, for instance, an electric field with which the ink Q is circulated in a direction of the arrow "a" in an ink flow path 30 of the ink jet head 50 and the positively charged particles in the ink Q (ink droplet) ejected from a tip end portion 14a of an ink guide 14 of an individual electrode are attracted by a recording medium P, that is, a flying electric field is formed between first and second drive electrodes 18a and 44 and the recording medium P. A distance (gap) between the tip end portion 14a of the ink guide 14 and the recording medium P is set in a range of 200 to 1000 μm, for instance. When the gap is set at 500 μm, the flying electric field is formed by providing a potential difference in a range of 1 kV to 2.5 kV.

Also, by an average voltage applied to the first or second drive electrode 18a or 44, an induced voltage that is lower than the average voltage is almost constantly generated in a floating conduction plate 26, so that an

electric field (hereinafter referred to as the "migration electric field", for instance) is formed with which the positively charged particles in the ink Q in the ink flow path 30 functioning as an ink reservoir are attracted upward and the positively charged particles in the ink Q gather in the upper portion of the ink flow path 30. By providing a potential difference of around several hundred V with respect to a thickness of the ink flow path 30 of several mm, for instance, the migration electric field is formed.

[0077]

For instance, in the ink jet head 50 shown in Fig. 12, the recording medium P is charged to a negative high voltage of -1.5 kV (or a counter electrode formed by a transport member 52 that transports the recording medium P is biased to -1.5 kV) and the first and second drive electrodes 18a and 44 are both set at 0 V (ground state), thereby forming the flying electric field. Then, the guard electrode 54 is set at 0 V (ground state).

Under this state, the ink Q moves upward from the ink flow path 30 to a space between the through hole 58 and the ink guide 14 and gathers in the tip end portion 14a by electrophoretic action and capillary action. The ink Q gathering in the tip end portion 14a is retained in the tip end portion 14a by the surface tension or the like of the ink Q and the concentration of the positively charged particles in the ink Q is increased to a high level.

[0078]

Next, as shown in Fig. 13, pulse voltages (that are both in the range of +400 to 600 V, for instance) are applied to the first and second drive electrodes 18a and 44 in accordance with an image signal and an ink droplet

R having highly concentrated positively charged particles is ejected from the tip end portion 14a of the ink guide 14. For instance, when the initial particle concentration is in a range of 3 to 15%, it is preferable that the particle concentration in the ejected ink droplet R is 30% or higher. Note that the pulse widths of the pulse voltages are not specifically limited, but it is possible to set the pulse widths in the range of several tens of μs to several hundred μs, for instance. Also, the sizes of dots recorded on the recording medium P depend on the magnitudes or application time lengths of the pulse voltages, so that it is possible to adjust the dot sizes by adjusting the pulse voltage magnitudes or application time lengths.

In this embodiment as well, the ratio between the projection amount of the tip end portion 14a of the ink guide 14 and the inside diameter of the first drive electrode 18a is set so as to fall within the aforementioned appropriate limit range. Therefore, it becomes possible to appropriately adjust the flying electric field between the first and second drive electrodes 18a and 44 and the recording medium P and to cause ink ejection with reliability and stability only when appropriate pulse voltages are applied to the first and second drive electrodes 18a and 44. Also, in the illustrated example, the first and second drive electrodes 18a and 44 are matrix-driven, so that it becomes possible to reduce the number of drivers.

That is, an attraction electric field toward the recording medium is set so as to fall within a range of 1.5×10^7 V/m or lower, more preferably 1.0×10^7 V/m or lower under a state where the ink droplet ejection is not caused, and to fall within a range of 2.0×10^7 V/m or

higher, more preferably 2.5×10^7 V/m or higher under a state where the ejection is caused.

[0079]

It should be noted here that in the ink jet head 50 of this embodiment, it is not specifically limited whether the ink ejection/non-ejection is controlled using one or both of the first drive electrodes 18a and the second drive electrodes 44. However, it is preferable that the ejection of the ink Q is not performed when one of the first drive electrodes 18a and the second drive electrodes 44 are set at the ground level and the ink ejection is performed only when the first drive electrodes 18a are set under the high-impedance state or at the high-voltage level and the second drive electrodes 44 are set at the high-voltage level.

[0080]

By the way, as in the illustrated example, the guard electrode 54 is provided between adjacent first drive electrodes 18a in the ink jet head 50 of this embodiment, but the present invention is not limited to this. For instance, when the first and second drive electrodes 18a and 44 are matrix-driven, that is, when the second drive electrodes 44 of the lower layer are sequentially driven in units of columns and the first drive electrodes 18a of the upper layer are driven in accordance with image data, the guard electrode may be provided only in spaces between the rows of the first drive electrodes 18a. Even in this case, by biasing the guard electrode to a predetermined guard potential (ground level, for instance) at the time of recording, it becomes possible to eliminate the influence of adjacent individual electrodes.

[0081]

Also, in this embodiment, when the rows of the first drive electrodes 18a of the upper layer are sequentially turned on and the second drive electrodes 44 of the lower layer are turned on/off in accordance with image data at the time of driving of the ejection electrodes 18 of the individual electrodes like in the embodiment shown in Figs. 8(a) and 8(b), that is, when the arrangement of the rows and columns is interchanged, the second drive electrodes 44 are driven in accordance with the image data. Therefore, the individual electrodes on both sides of each individual electrode in the column direction are frequently switched between the high-voltage level and the ground level.

In the row direction, however, the first drive electrodes 18a are driven in units of rows and the first drive electrodes 18a of the individual electrodes on both sides of a currently driven row are constantly set at the ground level. Consequently, the rows of the individual electrodes on the both sides play the role of a guard electrode. As described above, when each row of the first drive electrodes 18a of the upper layer are sequentially turned on and the second drive electrodes 44 of the lower layer are driven in accordance with image data, it becomes possible to eliminate the influence of adjacent individual electrodes and to improve recording quality without providing a guard electrode.

Needless to say, in any of the embodiments described above, it is possible to eliminate the influence of adjacent individual electrodes by providing a guard electrode.

[0082]

Further, in the ink jet head 50 of this embodiment, the floating conduction plate 26 is provided which

constitutes the undersurface of the ink flow path 30 and causes the positively charged ink particles (charged particles, that is, charged fine particle component) in the ink flow path 30 to migrate upwardly (that is, toward the recording medium P side) by means of induced voltages generated by pulse-like ejection voltages applied to the first drive electrodes 18a and the second drive electrodes 44. Also, an electrically insulative coating film (not shown) is formed on a surface of the floating conduction plate 26, thereby preventing a situation where the physical properties and components of the ink are destabilized due to charge injection into the ink or the like. It is preferable that the electric resistance of the insulative coating film is set at 10^{12} Ω·cm or higher, more preferably at 10^{13} Ω·cm or higher. Also, it is preferable that the insulative coating film is corrosion resistant to the ink, thereby preventing a situation where the floating conduction plate 26 is corroded by the ink. Further, the floating conduction plate 26 is covered with an insulation member from its bottom side. With this construction, the floating conduction plate 26 is completely electrically insulated and floated.

Here, at least one floating conduction plate 26 is provided for each head. (For example, in the heads for C, M, Y, and K, each head is provided with at least one floating conduction plate and the heads for C and M will never share the same floating conduction plate.)

[0083]

In the respective embodiments of the electrostatic ink jet heads having the ejection electrodes of the two-layered electrode structure as described above, the counter electrode (recording medium P) may be charged

to -1.6 kV, for instance, and the ink ejection may be controlled so that the ink will not be ejected when at least one of the first drive electrodes and the second drive electrodes are set at a negative high voltage (-600 V, for instance) and the ink will be ejected only when both of the first drive electrodes and the second drive electrodes are set at the ground level (0 V).

[0084]

It should be noted that the ink Q to be supplied to the ink flow path 30 in the present invention contains charged color particles (charged color fine particle component) whose particle size is around 0.1 to 5 μm and which are dispersed in a carrier liquid. Note that dispersion resin particles for improving fixability of an image after printing may be contained in the ink Q as appropriate together with the charged color particles. It is required that the carrier liquid is a dielectric liquid (non-aqueous solvent) having a high electric resistivity (10^9 Ω·cm or higher, preferably 10^{10} Ω·cm or higher). If a carrier liquid having a low electric resistivity is used, the carrier liquid itself is charged by charge injection by the voltages applied from the ejection electrodes, so that it becomes difficult to increase the concentration of the charged particles (charged fine particle component) and therefore concentration does not occur. Also, the carrier liquid having a low electric resistivity is not suited for the present form because there is apprehension that electrical breakdown or continuity may occur between adjacent recording electrodes.

[0085]

It is preferable that the relative permittivity of the dielectric liquid used as the carrier liquid is 5 or

lower, more preferably 4 or lower, and still more preferably 3.5 or lower. By setting the relative permittivity in such a range, an electric field effectively acts on the charged particles in the dielectric liquid and migration easily occurs.

It should be noted here that it is preferable that the upper limit value of the inherent electric resistance of the dielectric liquid is around 10^{16} Ωcm, and the lower limit value of the relative permittivity thereof is around 1.9.

The reason why it is preferable that the electric resistance of the dielectric liquid is in the range described above is that if the electric resistance is lowered, it becomes impossible to perform ejection of the ink under a low electric field with stability. On the other hand, the reason why it is preferable that the relative permittivity is in the range described above is that if the dielectric constant is increased, the electric field is weakened due to polarization of the solvent and therefore colors of dots formed are thinned or blurring occurs.

[0086]

Preferred examples of the dielectric liquid of the present invention include straight-chain or branched aliphatic hydrocarbons, alicylic hydrocarbons, aromatic hydrocarbons, or halogen substituents of the hydrocarbons. For example, hexane, heptane, octane, isooctane, decane, isodecane, decalin, nonane, dodecane, isododecane, cyclohexane, cyclooctane, cyclodecane, benzene, toluene, xylene, mesitylene, Isopar C, Isopar E, Isopar G, Isopar H, Isopar L (Isopar: a trade name of EXXON Corporation), Shellsol 70, Shellsol 71 (Shellsol: a trade name of Shell Oil Company), AMSCO OMS, AMSCO 460 Solvent, (AMSCO: a

trade name of American Mineral Spirits Company), a silicone oil (such as KF-96L, manufactured by Shin-Etsu Silicones), etc. may be used singly or as a mixture of those.

[0087]

As to the color particles dispersed in the dielectric liquid (non-aqueous solvent), a colorant itself or the colorant contained in dispersion resin particles for improving fixability may be used. In the latter case, the color particles with pigments or the like are generally formed as resin-coated particles by coating pigments or the like with the resin material of the dispersion resin particles, or the color particles with dyes or the like are generally obtained as color particles by coloring the dispersion resin particles with dyes. As the colorant, it is possible to use any of pigments and dyes conventionally used in an ink jet ink composition, a printing (oil-based) ink composition, and an electro-photographic liquid developer.

[0088]

The content of the ink particles (total content of the color particles and/or the resin particles) dispersed in the ink is preferably in a range of 0.5 to 30 wt% based on the total weight of the ink, more preferably in a range of 1.5 to 25 wt%, and still more preferably in a range of 3 to 20 wt%. If the content of the ink particles is lowered, there easily occurs a problem that, for instance, shortage of the density of a printed image occurs or affinity of the ink with the recording medium surface is hardly obtained and therefore it becomes difficult to obtain a firmly fixed image. On the other hand, if the content of the ink particles is increased, there occurs a problem that, for instance, it becomes

difficult to obtain a uniform dispersion liquid or clogging of the ink easily occurs in the ejection head and therefore it becomes difficult to achieve stable ink ejection.

[0089]

Pigments to be used as colorants may be inorganic pigments or organic pigments commonly employed in the field of printing technology. Specific examples thereof include, but are not particularly limited to, well-known pigments such as Carbon Black, Cadmium Red, Molybdenum Red, Chrome Yellow, Cadmium Yellow, Titanium Yellow, chromium oxide, Viridian, Cobalt Green, Ultramarine Blue, Prussian Blue, Cobalt Blue, azo pigments, phthalocyanine pigments, quinacridone pigments, isoindolinone pigments, dioxazine pigments, threne pigments, perylene pigments, perinone pigments, thioindigo pigments, quinophthalone pigments, and metal complex pigments.

[0090]

Preferred examples of dyes to be used as colorants include oil-soluble dyes such as azo dyes, metal complex salt dyes, naphthol dyes, anthraquinone dyes, indigo dyes, carbonium dyes, quinoneimine dyes, xanthene dyes, aniline dyes, quinoline dyes, nitro dyes, nitroso dyes, benzoquinone dyes, naphthoquinone dyes, phthalocyanine dyes, and metal phthalocyanine dyes.

[0091]

Also, the average particle size of the ink particles, such as the color particles and/or resin particles, dispersed in the dielectric solvent is preferably in a range of 0.1 μm to 5 μm, more preferably in a range of 0.2 μm to 1.5 μm, and still more preferably in a range of 0.4 μm to 1.0 μm. The particle size was obtained using

CAPA-500 (a product manufactured by HORIBA, Ltd.).

[0092]

Here, it is preferable that the ink particles (dispersion resin particles and/or color particles or colorant particles) in the ink Q are positively or negatively charged particles.

It is possible to impart charge to the ink particles by appropriately using a technique of electro-photographic developer. In more detail, it is possible to impart the charge to the ink particles using charge detection agent and/or other additives described in "Latest Systems for Electro-photographic Development, and Development and Application of Toner Materials" (pp. 139 to 148), "Fundamentals and Applications of Electro-photographic Techniques" (edited by Electro-photographic Society, pp. 497 to 505, CORONA PUBLISHING CO., LTD., 1988), "Electro-photography" (Yuji Harasaki, Vol. 16 (No.2), p. 44, 1977), and the like.

[0093]

Also, the viscosity of the ink composition is preferably in a range of 0.5 to 5 mPa·sec, more preferably in a range of 0.6 to 3.0 mPa·sec, and still more preferably in a range of 0.7 to 2.0 mPa·sec. The color particles have electric charges and it is possible to use various charge control materials used for electro-photographic liquid developer as necessary. The charge amount thereof is preferably in a range of 5 to 200 μC/g, more preferably in a range of 10 to 150 μC/g, and still more preferably in a range of 15 to 100 μC/g. Also, there is a case where the electric resistance of the dielectric solvent changes due to addition of the charge control material. The charge detection agent is added so that the distribution factor P defined below

becomes preferably 50% or higher, more preferably 60% or higher, and still more preferably 70% or higher.

$$P=100\times(\sigma1-\sigma2)/\sigma1$$

Here, $\sigma1$ is the electric conductivity of the ink composition and $\sigma2$ is the electric conductivity of a supernatant of the ink composition obtained with a centrifugal separator. The electric conductivity is a value measured using an LCR meter (AG-4311 manufactured by Ando Electric Co., Ltd.) and an electrode for liquid (LP-05 manufactured by Kawaguchi Electric Works Co., Ltd.) by applying a voltage of 5 V at a frequency of 1 kHz. Also, the centrifugation was performed using a high speed refrigerated microcentrifuge (SRX-201 manufactured by TOMY SEIKO CO., LTD.) for 30 minutes at a rotation speed of 14500 rpm under a temperature of 23°C.

With the ink composition described above, migration of the charged particles easily occurs and concentration is facilitated.

[0094]

On the other hand, the electric conductivity $\sigma1$ of the ink composition is preferably in a range of 100 to 3000 pS/cm, more preferably in a range of 150 to 2500 pS/cm, and still more preferably in a range of 200 to 2000 pS/cm. By setting the electric conductivity in this range, voltages applied to the ejection electrodes are prevented from becoming extremely high and therefore there is eliminated apprehension that electrical breakdown or continuity may occur between adjacent ejection electrodes. Also, the surface tension of the ink composition is preferably in a range of 15 to 50 mN/m, more preferably in a range of 15.5 to 45 mN/m, and still more preferably in a range of 16 to 40 mN/m. By setting the surface tension in this range, the

voltages applied to the ejection electrodes are prevented from becoming extremely high and therefore there is prevented a situation where the head is soiled with ink leaking and spreading around the head.

[0095]

In a conventional ink jet system, ink is caused to fly toward a recording medium by applying a force to the entire ink. In the present invention, however, the charged fine particle component (charged toner particles) that is a solid component dispersed in the carrier liquid mainly receives a force and is caused to fly toward the recording medium. As a result, it becomes possible to record an image on various recording media, such as a nonabsorbable film like a PET film, as well as plain paper. Also, it becomes possible to obtain an image having high image quality on various recording media by preventing blurring or flowing of the ink on the recording media.

[0096]

Next, the electrostatic ink jet recording apparatus according to the third aspect of the present invention which uses the ink jet heads according to the first and second aspects of the present invention as well as the electrostatic ink jet recording method according to the fourth aspect of the present invention performed by using these ink jet heads will be described.

Fig. 14 is a schematic diagram showing an overall construction of an embodiment of the electrostatic ink jet recording apparatus according to the third aspect of the present invention.

The electrostatic ink jet recording apparatus (hereinafter referred to as the "ink jet printer") and the electrostatic ink jet recording method of the present

invention are used to record a full-color image by forming an image of ink particles through ejection of ink droplets in four colors in accordance with inputted image data using an image forming means onto a recording medium P transported by a transport means and fixing the image of ink particles formed on the recording medium P.

[0097]

An ink jet printer 60 shown in the figure is an apparatus that performs one-sided four-color printing on the recording medium P. For this purpose, as a means for transporting the recording medium P, the ink jet printer 60 includes a feed roller pair 62, a guide 64, rollers 66a, 66b, and 66c, a transport belt 68, a transport belt position detection means 69, an electrostatic adsorption means 70, a discharge means 72, a peeling means 74, a fixing/transporting means 76, and a guide 78. Also, as the image forming means, the ink jet printer 60 includes an ejection head unit 80, an ink circulation system 82, a head driver 84, a recording medium position detection means 86, and a recording position control means 88. Further, the ink jet printer 60 includes a discharge fan 90 and a solvent collecting device 92 as the solvent collecting means. These construction elements are provided in an enclosure 61.

[0098]

First, the transport means for the recording medium P in the ink jet printer 60 will be described.

The feed roller pair 62 is provided adjacent to an inlet 61a provided on a side surface of the enclosure 61 and is composed of a pair of rollers that feed the recording medium P from a not-shown stocker to the transport belt 68 (portion supported by the roller 66a)

provided in the enclosure 61. The guide 64 is provided between the feed roller pair 62 and the roller 66a supporting the transport belt 68, and guides the recording medium P to the transport belt 68.

[0099]

Although not illustrated, it is preferable that a foreign matter removing means for removing foreign matters, such as dust or paper waste, adhering to the recording medium P is provided in proximity to the feed roller pair 62. As the foreign matter removing means, a means based on a known non-contact method, such as suction removal, blowing-off removal, or electrostatic removal, or a means based on a contact method using a brush, a roller, or the like may be used alone or in combination. Also, the feed roller pair 62 may be constructed using slightly adhesive rollers and a cleaner may be provided in the feed roller pair 62, which removes foreign matters, such as dust or paper waste, at the time of feeding of the recording medium P by the feed roller pair 62.

[0100]

The rollers 66a, 66b, and 66c stretch and move the transport belt 68, and at least one of the rollers 66a, 66b, and 66c is connected to a not-shown drive source.

The transport belt 68 functions as a platen for holding the recording medium P and moves the recording medium P at the time of image formation by ink ejected from the ejection head unit 80, and transports the recording medium P to the fixing/transporting means 76 after the image formation. Consequently, an endless belt made of a material that has superior dimensional stability and high endurance is used as the transport belt 68. As the material thereof, a metal, a polyimide

resin, a fluororesin, another resin, or a complex thereof is used, for instance.

[0101]

In this embodiment shown in the figure, the recording medium P is held on the transport belt 68 through electrostatic adsorption, so that a side (front surface) of the transport belt 68 holding the recording medium P is insulative and a side (back surface) of the transport belt 68 contacting the rollers 66a, 66b, and 66c is conductive. In more detail, the transport belt 68 is a belt produced by applying a fluororesin coat to the front surface of a metallic belt. Also, in the illustrated example, the roller 66a is a conductive roller and the back surface (metallic surface) of the transport belt 68 is grounded through the roller 66a.

In other words, when holding the recording medium P, the transport belt 68 functions as the counter electrode 20 consisting of the conductive electrode substrate 20a and the insulation sheet 20b as shown in Fig. 14, and is an example of the transport member 52 for the transport of the recording medium P that constitutes the counter electrode 20 shown in Fig. 6.

[0102]

It should be noted here that aside from this, a belt having a metallic layer produced with various methods, such as a method with which a metallic belt is coated with any one of the resin materials described above, a method with which a resin sheet and a metallic belt are bonded to each other using an adhesive or the like, or a method with which a metal is vapor-deposited on the back surface of a belt made of the above-mentioned resin, may be suitably used as the transport belt 68.

Also, it is preferable that the surface of the transport belt 68 contacting the recording medium P is made smooth, because with this construction, a favorable adsorption property is obtained for the recording medium P.

[0103]

It should be noted here that it is preferable that meandering of the transport belt 68 is suppressed with a known method. For instance, the meandering of the transport belt 68 may be suppressed using a method with which tension at both ends in the widthwise direction of the transport belt is changed by setting the roller 66c as a tension roller and tilting the axis of the roller 66c with respect to the axes of the roller 66a and the roller 66b in accordance with an output from the transport belt position detection means 69, that is, a detected position of the transport belt 68 in the widthwise direction. Alternatively, the meandering may be suppressed by forming the rollers 66a, 66b, and 66c in a tapered shape or a crown shape, for instance.

The transport belt position detection means 69 detects the position in the widthwise direction of the transport belt 68. With reference to the detected position, the suppression of the meandering of the transport belt described above is performed. In addition, using the detection result, a position in the sub-scanning direction of the recording medium P at the time of image recording is regulated to a predetermined position. The transport belt position detection means 69 performs the detection using a known detection means such as a photosensor.

[0104]

The electrostatic adsorption means 70 charges the

recording medium P to a predetermined potential, as a result of which the recording medium P is adsorbed and held on the transport belt 68 by means of an electrostatic force and applied with a predetermined bias with respect to the ejection head unit 80 for image formation.

In this embodiment, the electrostatic adsorption means 70 includes a scorotron charger 70a for charging the recording medium P and a negative high voltage power supply 70b connected to the scorotron charger 70a. The recording medium P is charged to a negative high voltage by the scorotron charger 70a connected to the negative high voltage power supply 70b and is electrostatically adsorbed on the insulation layer of the transport belt 68.

It should be noted here that the electrostatic adsorption means 70 has substantially the same construction as the charge unit 22 shown in Fig. 1, and has the same function in that the recording medium P is charged to a predetermined potential.

[0105]

The electrostatic adsorption means is not limited to the scorotron charger 70a of the illustrated example, and it is also possible to use various other means and methods such as a corotron charger, a solid charger, a discharge needle, and the like. Also, as will be described in detail later, the electrostatic adsorption means 70 may be configured such that at least one of the rollers 66a, 66b, and 66c is set as a conductive roller or a conductive platen is arranged on the back surface side (side opposite to the recording medium P) of the transport belt 68 at a recording position to the recording medium P. In this

case, the conductive roller or the conductive platen is connected to a negative high voltage power supply. Alternatively, the transport 68 may be set as an insulative belt, the conductive roller may be grounded, and the conductive platen may be connected to the negative high voltage power supply.

[0106]

After the recording medium P is electrostatically adsorbed on the transport belt 68 by means of an electrostatic force so that no floating of the recording medium P occurs, the electrostatic adsorption means 70 uniformly charges a surface of the recording medium P transported by the transport belt 68. Here, the transport speed of the transport belt 68 at the time of the charge of the recording medium P need only be in a range in which the charge is performed with stability, and it does not matter whether this transport speed is the same as or is different from a transport speed at the time of image recording. Also, by circulating the recording medium P multiple times, the electrostatic adsorption means may charge the same recording medium P multiple times and achieve uniform charge.

It should be noted here that in this embodiment, the electrostatic adsorption and charge of the recording medium P are both performed using the electrostatic adsorption means 70. However, a charge means may be provided separately from the electrostatic adsorption means.

[0107]

The recording medium P charged by the electrostatic adsorption means 70 is transported to the position of the ejection head unit 80 to be described later by the

transport belt 68. In the image forming portion by the ejection head unit 80, a recording signal voltage is applied to the ejection head unit 80 by regarding the charge potential of the recording medium P as a bias. The recording signal voltage is thus superimposed on the bias charge potential thereby ejecting ink (droplets) and forming an image on the recording medium P. Here, by providing a means for heating the transport belt 68 and increasing the temperature of the recording medium, fixation of the ink droplets ejected from the ejection head unit 80 on the print medium may be accelerated. In this case, it becomes possible to further suppress blurring and improve image quality. An image recording method performed by using the ejection head unit 80 for implementing the recording method of the present invention will be described in detail later.

[0108]

The recording medium P, on which an image has been formed, is discharged by the discharge means 72, is peeled off the transport belt 68 by the peeling means 74, and is transported to the fixing/transporting means 76.

In this embodiment, the discharge means 72 includes a corotron discharger 72a, an AC power supply 72b, and a DC high voltage power supply 72c, with a terminal of the DC high voltage power supply 72c on one side being grounded. The discharge means 72 of the illustrated example uses a so-called AC corotron discharger that uses the corotron discharger 72a and the AC power supply 72b, although it is possible to use various other means and methods such as a scorotron discharger, a solid discharger, and a discharge needle, for instance. In addition, a construction using a conductive roller or a conductive platen is suitably used like in the case of

the electrostatic adsorption means 70 described above. Also, as the peeling means 74, it is possible to use various known techniques such as a peeling blade, a reverse rotation roller, and an air knife.

[0109]

The recording medium P peeled off the transport belt 68 is sent to the fixing/transporting means 76, which then fixes the image formed by the ink. In this embodiment, as the fixing/transporting means 76, a roll pair composed of a heat roll 76a and a transport roll 76b is used. With this construction, during the transport of the recording medium P by the fixing/transporting means 76, fixing of the image formed on the recording medium P is achieved through contact heating. In the present invention, however, a fixing means may be provided separately from the transport means composed of the transport roll pair to perform fixing by another fixing means or fixing method.

[0110]

In addition to the fixing using the heat rolls described above, commonly known heat-fixing means such as irradiation by an infrared ray lamp, a halogen lamp or a xenon flash lamp, or hot-air fixing using a heater can be used for the heat-fixing.

In the case of heat-fixing, when coated paper or laminated paper is used as the recording medium P, there occurs a phenomenon called "blister" where moisture in the paper is abruptly vaporized due to a sudden increase in temperature and projections and depressions occur to the paper surface. In order to prevent this phenomenon, it is preferable that the paper temperature is gradually increased by, for instance, arranging multiple fixing devices and changing at least one of the electric power

supply to each fixing device and a distance from each fixing device to the recording medium P.

[0111]

It is preferable that at least in a process from the image formation by the ink from the ejection head unit 80 to the fixing by the fixing/transporting means 76, the image forming surface of the recording medium P is maintained so as not to contact anything.

The moving speed of the recording medium P at the time of fixing by the fixing/transporting means 76 is not specifically limited and may be the same as or different from the transport speed by the transport belt 68 at the time of image formation. When the moving speed of the recording medium P is different from the transport speed at the time of image formation, it is also preferable that a speed buffer is provided for the recording medium P immediately before the fixing/transporting means 76.

The recording medium P, on which an image has been fixed, is discharged onto the not-shown discharged sheet stocker while being guided by the guide 78.

[0112]

Next, an image forming (drawing) means in the ink jet printer 60 and an image recording method performed thereby will be described.

As described above, the image forming means of the ink jet printer 60 includes the ejection head unit 80 for ejecting ink, the ink circulation system 82 that supplies the ink to the ejection head unit 80 and recovers the ink from the ejection head unit 80, the head driver 84 that drives the ejection head unit 80 in accordance with an output image signal from a not-shown external apparatus such as a computer or RIP (a Raster Image Processor), the recording medium position detection means 86 for

detecting the recording medium P in order to determine an image formation (recording) position on the recording medium P, and the recording position control means 88 for controlling the position of the ejection head unit 80.

[0113]

Fig. 15 is a schematic perspective view showing the ejection head unit 80, the recording position control means 88, and the transport means for the recording medium P on the periphery thereof.

The ejection head unit 80 includes ejection heads 80a for four colors of cyan (C), magenta (M), yellow (Y), and black (K) for recording a full-color image, and forms an image on the recording medium P transported by the transport belt 68 at a predetermined speed by ejecting ink supplied by the ink circulation system 82 as ink droplets in accordance with signals from the head driver 84. The electrostatic ink jet heads for the respective colors are arranged along a traveling direction of the transport belt 68. The ejection heads 80a for the respective colors in the ejection head unit 80 are constructed of the electrostatic ink jet heads of the present invention, to be more specific, various ink jet heads of various head structures as shown in Fig. 1 to Fig. 13, in particular the electrostatic ink jet head 50 whose head structure is shown in Fig. 9 to Fig. 13.

[0114]

Regarding the ejection head unit 80, it is possible to use a multi-channel head in which multiple nozzles (each nozzle corresponds to one unit of the ejection head that ejects ink droplets) are arranged at predetermined intervals in a direction (widthwise direction) orthogonal to the transport direction of the recording medium P.

Alternatively, it is possible to use a full-line head in which nozzles for the respective colors are arranged in an entire area in the widthwise direction of the recording medium P.

The ink jet printer 60 of the illustrated example performs main scanning by transporting the recording medium P with respect to the ejection head unit 80 using the transport belt 68. With this construction, the ink jet printer 60 of the illustrated example becomes capable of performing image formation (drawing) at a higher speed as compared with a case of a commercially available ink jet printer that serially scans its ejection head.

[0115]

When the multi-channel head is used as the ejection head unit 80, the main scanning is performed by transporting the recording medium P with respect to the ejection head unit 80 through rotation of the transport belt 68 under a state where the recording medium P is held on the transport belt 68. Also, sub-scanning is performed by continuously moving the ejection head unit 80 in the widthwise direction of the transport belt 68 or by sequentially (intermittently) moving the ejection head unit 80 in the widthwise direction each time the transport belt 68 makes one rotation. In this manner, an image is formed on the recording medium P. Consequently, in order to form an image on the entire area of the recording medium P, the transport belt 68 is rotated multiple times while holding the recording medium P, that is, the main scanning is performed multiple times. Note that an sub-scanning method of the ejection head unit 80 in this case may be selected as appropriate in accordance with the relation between the nozzle density

of the ejection head unit 80 and drawing resolution, an interlace method, and the like.

[0116]

Further, when the full-line head is used as the ejection head unit 80, an image is formed on the entire area of the recording medium P merely by transporting the recording medium P held on the transport belt 68 with respect to the ejection head unit 80 and having the recording medium P pass by the ejection head unit 80 once, that is, by performing scanning only once.

After an image is formed on the entire area of the recording medium P by the ejection head unit 80 (the multi-channel head or the full-line head) in this manner, the recording medium P is nipped and transported by the fixing/transporting means 76, during which the formed image is fixed by the fixing/transporting means 76.

[0117]

It should be noted here that in the embodiment described above, when the ejection head unit 80 uses the multi-channel head, the main scanning is performed by transporting the recording medium P in a transport direction of the transport belt 68 using the transport belt 68 and the sub-scanning is performed by moving the ejection head unit 80 in the widthwise direction of the transport belt 68, that is, in a direction approximately orthogonal to the main scanning direction. Also, when the ejection head unit 80 uses the full-line head, the entire surface of the recording medium P is scanned by transporting the recording medium P in the transport direction of the transport belt 68 using the transport belt 68. However, the present invention is not limited to this and any other scanning method may be used so long

as it is possible to scan the entire surface of the recording medium P with the ejection head unit 80 by relatively moving the recording medium P and the ejection head unit 80. For instance, the main scanning may be performed by moving the ejection head unit 80 in the widthwise direction of the transport belt 68 and the sub-scanning may be performed by transporting the recording medium P using the transport belt 68. Alternatively, the main scanning and the sub-scanning may be performed by transporting the transport belt 68 in the transport direction of the transport belt 68 and moving the transport belt 68 in the widthwise direction of the transport belt 68 while fixing the ejection head unit 80. Still alternatively, the recording medium P may be held on a holding means at a predetermined position, for instance, the recording medium P is stationarily held on the transport belt 68 stopped at a predetermined position, and the entire surface of the recording medium P may be scanned by one-dimensionally moving the ejection head unit 80, in the case of the full-line head, or by two-dimensionally moving the ejection head unit 80, in the case of the multi-channel head.

[0118]

Next, in order to have ink, whose amount is sufficient for ink ejection, flow through the ink flow path 30 (see Fig. 13, for instance) of the ink jet head 50 used in each ejection head 80a for each color of the ejection head unit 80, the ink circulation system 82 includes an ink circulation apparatus 82a including an ink tanks, a pump, a replenishing ink tank (not shown), and the like for each of four colors (C, M, Y, and K). The ink circulation system 82 also includes an ink supplying system 82b that includes ink supplying paths

each composed of an ink distribution pipe system for each color for supplying the ink in each color from each ink tank of the ink circulation apparatus 82a to the ink flow path 30 (see Fig. 13, for instance) of the ink jet head 50 used in each ejection head 80a for each color of the ejection head unit 80 (from the right side in Fig. 13). The ink circulation system 82 further includes an ink recovery system 82c that includes ink recovery paths each composed of an ink distribution pipe system for each color for recovering the ink from the ink flow path 30 (from the left side in Fig. 13) of the ink jet head 50 used in each ejection head 80a for each color of the ejection head unit 80 to the ink circulation apparatus 82a.

[0119]

The ink circulation system 82 is not specifically limited so long as it is possible to circulate the ink by supplying the ink from the ink tanks of the ink circulation apparatus 82a to the ejection head unit 80 through the ink supplying system 80b independently of respective colors and recovering the ink from the ejection head unit 80 to the ink tanks through the ink recovery system 82c independently of respective colors. Each ink tank reserves the ink in a corresponding color for image recording, with the reserved ink being pumped up by a pump and sent to the ejection head unit 80. The ejection of the ink from the ejection head unit 80 lowers the concentration of the ink circulated by the ink circulation system 82, so that it is preferable that the ink circulation system 82 is constructed so that the ink concentration is detected using an ink concentration detector and the ink is refilled as appropriate from the replenishing ink tanks in accordance with the detected

ink concentration. With this construction, it becomes possible to maintain the ink concentration in a predetermined range.

[0120]

Also, it is preferable that the ink tanks are each provided with a stirring apparatus for suppressing deposition/coagulation of a solid component of the ink and an ink temperature management apparatus for suppressing changes in temperature of the ink. This is because if the temperature management is not performed, the ink temperature changes due to changes in environmental temperature or the like and therefore there occur changes in physical properties of the ink and in size of dots, so that there is a possibility that it may become impossible to form high-quality images with stability.

As the stirring apparatus, it is possible to use a rotary blade, an ultrasonic transducer, a circulation pump, or the like.

As the ink temperature control apparatus, it is possible to use various known methods such as a method with which a heat generation element or a cooling element, such as a heater or a Peltier element, is provided for the ejection head unit 80, the ink tanks, the ink distribution pipe systems, or the like and the ink temperature is controlled using a temperature sensor such as a thermostat. When the temperature control apparatus is arranged in the ink tanks, it is preferable that the temperature control apparatus is arranged together with a stirring apparatus, thereby making it possible to maintain a temperature uniform in the tank. The stirring apparatus, with which a density in each tank is maintained uniform, may be used also as the stirring

apparatus that suppresses the deposition/coagulation of the solid component of the ink.

[0121]

The head driver 84 receives image data from a system control portion (not shown) that receives image data from an external apparatus and performs various processing on the image data, and drives the ejection head unit 80 based on the image data. The system control portion color-separates the image data received from the external apparatus such as a computer, an RIP, an image scanner, a magnetic disk apparatus, or an image data transmission apparatus. The system control portion then performs division computation into an appropriate number of pixels and an appropriate number of gradations, performs screening processing, performs computation of a halftone dot area ratio on the color-separated data, and outputs head drive data corresponding to the image data to the head driver 84. The head driver 84 drives the ejection head unit 80 (ink jet head 50) in accordance with the head drive data.

[0122]

Also, the system control portion controls movement of the ejection head unit 80 (recording position control means 88) and timings of ink ejection by the ejection head unit 80 in accordance with transport timings of the recording medium P by the transport belt 68. The ejection timings are controlled using an output from the recording medium position detection means 86 or an output signal from an encoder or a photo interpreter arranged for the transport belt 68 or a drive means of the transport belt 68.

The recording medium position detection means 86 detects the recording medium P transported to a position

at which the ejection head unit 80 ejects ink droplets, and may be any known detection means such as a photosensor.

[0123]

The recording position control means 88, on which the ejection head unit 80 is mounted/fixed, moves the ejection head unit 80 in the widthwise direction of the transport belt 68 and adjusts an image forming position onto the recording medium P in the widthwise direction. That is, in order to perform fine adjustment of image formation at a predetermined position on the recording medium P and to perform sub-scanning when the multi-channel head is used as the ejection head unit 80, the recording position control means 88 moves the ejection head unit 80 in accordance with the position of the transport belt 68 detected by the transport belt position detection means 69 and an image signal from the head driver 84.

[0124]

The solvent collecting means in the ink jet printer 60 will now be described.

The ink jet printer 60 includes the discharge fan 90 and the solvent collecting device 92 as the solvent collecting means to thereby collect a dispersion solvent that vaporizes from an ink droplet which was ejected from the ejection head unit 80 on the recording medium P and which includes a charged fine particle component and a dispersion solvent for dispersing the charged fine particle component therein, and in particular a dispersion solvent vaporizing from the recording medium P during the fixation of an image formed by the ink droplet.

The discharge fan 90 aspirates air in the enclosure 11 of the ink jet printer 60 and supplies it to the

solvent collecting device 92.

The solvent collecting device 92 is provided with a solvent vapor adsorbent. The solvent component of a solvent vapor-containing gas aspirated by the discharge fan 90 is adsorbed on the solvent vapor adsorbent and the gas from which the solvent has been removed by adsorption is then discharged outside the enclosure 11 of the ink jet printer 60. Various kinds of activated carbon can be suitably used for the solvent vapor adsorbent.

[0125]

Description has been made above on an electrostatic ink jet recording apparatus that records a color image using ink in four colors of C, M, Y, and K, although the present invention is not limited to this. For instance, the present invention may be applied to a monochrome recording apparatus or a recording apparatus that also uses ink in other colors such as light colors or special colors. In these cases, one or more ejection head units 80 and ink circulation systems 82 whose number corresponds to the number of ink colors are used.

[0126]

Also, in the embodiments described above, an ink jet recording apparatus has been described which performs image recording using ink ejected by positively charging color particles in ink and setting a recording medium or a counter electrode on the back surface of the recording medium at a negative high voltage. However, the present invention is not limited to this and may be applied to an apparatus that performs image recording using ink ejected by negatively charging color particles in ink and setting a recording medium or a counter electrode at a positive high voltage. When the polarity of the charged color particles are set opposite to that

in the embodiments described above in this manner, the polarities of voltages applied to the electrostatic adsorption means, the counter electrode, and the drive electrodes of the ink jet head and the like are set opposite to those in the embodiments described above.

[0127]

Further, the electrostatic ink jet head and the recording apparatus according to the present invention are not limited to the case where ink containing a charged colorant component is ejected. There is no particular limitation as far as the present invention is applied to a liquid ejection head that ejects liquid containing charged particles. For instance, in addition to the electrostatic ink jet recording apparatus as described above, the present invention can be applied to an application apparatus that applies liquid by ejecting droplets using charged particles.

[0128]

The electrostatic ink jet head, and the recording apparatus and the recording method using the electrostatic ink jet head according to the present invention have been described in detail above with reference to various embodiments, although the present invention is not limited to the embodiments described above. That is, it is of course possible to make various modifications and changes without departing from the gist of the present invention.

[0129]

[Effects of the Invention]

As described in detail above, according to the first and second aspects of the present invention, it becomes possible to provide an electrostatic ink jet head that is capable of achieving an ejection voltage reduction,

widening the choice of ink guide materials, for example, low dielectric constant material becomes usable, and widening the choice of ink guide tip end structures, for example, not-pointed shape becomes usable.

Also, according to the third and fourth aspects of the present invention, it becomes possible to provide a safe, low-cost, and widely applicable electrostatic ink jet recording apparatus and recording method that are capable of recording an image on a recording medium with stability by using the electrostatic ink jet head providing the effects described above.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] This is a schematic cross-sectional view showing an outlined construction of an embodiment of an electrostatic ink jet head according to the present invention.

[FIG. 2] (a) is a schematic perspective view showing an outlined construction of an embodiment of an individual electrode of the electrostatic ink jet head according to the present invention, and (b) is a schematic cross-sectional view of (a).

[FIG. 3] (a) is a schematic perspective view showing an outlined construction of another embodiment of the individual electrode of the electrostatic ink jet head according to the present invention, (b) is a schematic cross-sectional view of (a), (c) is a schematic horizontal cross-sectional view showing an outlined construction of still another embodiment of the individual electrode of the electrostatic ink jet head according to the present invention, and (d) is a schematic partial vertical cross-sectional view of (c).

[FIG. 4] This is a conceptual diagram showing a real model of the individual electrode of the

electrostatic ink jet head according to the present invention.

[FIG. 5] This is a graph showing a relationship between an electric field strength and a distance from a center of a tip end of an ink guide in the real model shown in Fig. 4.

[FIG. 6] (a) is a graph showing a relationship between a required pulse voltage and a ratio between a distance to an ejection portion and a circular ejection electrode inside diameter in the real model shown in Fig. 4, and (b) is a graph showing a relationship between a required pulse voltage and a ratio between the distance to the ejection portion and a parallel ejection electrode distance in the real model shown in Fig. 4.

[FIG. 7] (a) is a schematic perspective view showing an outlined construction of another embodiment of the individual electrode of the electrostatic ink jet head according to the present invention, and (b) is a schematic perspective view showing an embodiment of arrangement of first and second drive electrodes used as the individual electrode shown in (a).

[FIG. 8] (a) is a schematic perspective view showing an outlined construction of another embodiment of the individual electrode of the electrostatic ink jet head according to the present invention, and (b) is a schematic perspective view of an embodiment of arrangement of first and second drive electrodes used as the individual electrode shown in (a).

[FIG. 9] This is a schematic perspective view showing an outlined construction of another embodiment of the electrostatic ink jet head according to the present invention.

[FIG. 10] (a) is a schematic cross-sectional view

showing an outlined construction of the ink jet head shown in Fig. 9, and (b) is a cross-sectional view taken along a line VII-VII in (a).

[FIG. 11] (a), (b) and (c) are arrow views taken along lines A-A, B-B and C-C of Fig. 10(b), respectively.

[FIG. 12] This is a conceptual diagram illustrating an operation of the ink jet head shown in Fig. 9.

[FIG. 13] This is a conceptual diagram illustrating a recording operation of the ink jet head shown in Fig. 9.

[FIG. 14] This is a schematic construction diagram showing the ink jet recording apparatus according to an embodiment of the present invention.

[FIG. 15] This is a schematic perspective view showing an ejection head and recording medium transport means on the periphery of the ejection head.

[FIG. 16] This is a conceptual diagram showing an example construction of a conventional electrostatic ink jet head.

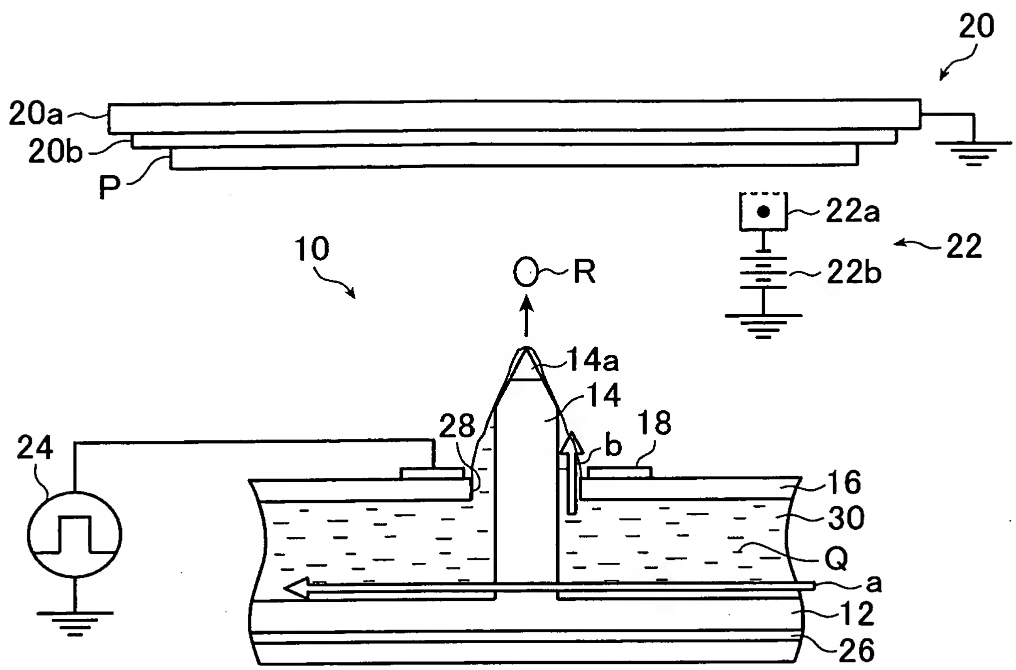
[Legend]

10, 32, 40, 41, 50 electrostatic ink jet head
12 head substrate
14 ink guide
14a tip end portion
16 insulating substrate
18 ejection electrode
18a circular electrode (first drive electrodes)
18b, 36 parallel electrode
20 counter electrode
20a electrode substrate
20b insulation sheet
22 charge unit
22a scorotron charger
22b bias voltage source

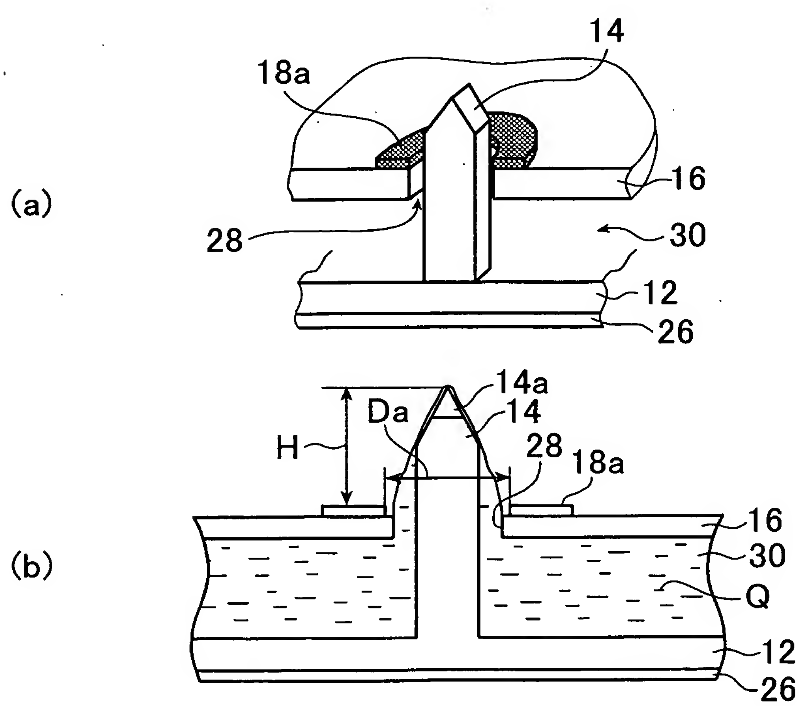
24 signal voltage source
26 floating conduction plate
28, 58 through hole
30 ink flow path
42, 44 second drive electrode
52 transport member
54 guard electrode
56a, 56b, 56c insulation layer
60 ink jet printer
62 feed roller
64 guide
66a, 66b, 66c roller
68 transport belt
69 transport belt position detection means
70 electrostatic adsorption means
72 discharge means
74 peeling means
76 fixing/transporting means
78 guide
80, 80a ejection head
82 ink circulation system
84 head driver
86 recording medium position detection means
88 recording position control means
90 discharge fan
92 solvent collecting device
P recording medium
Q ink
R ink droplet

【TYPE OF THE DOCUMENT】 Drawings

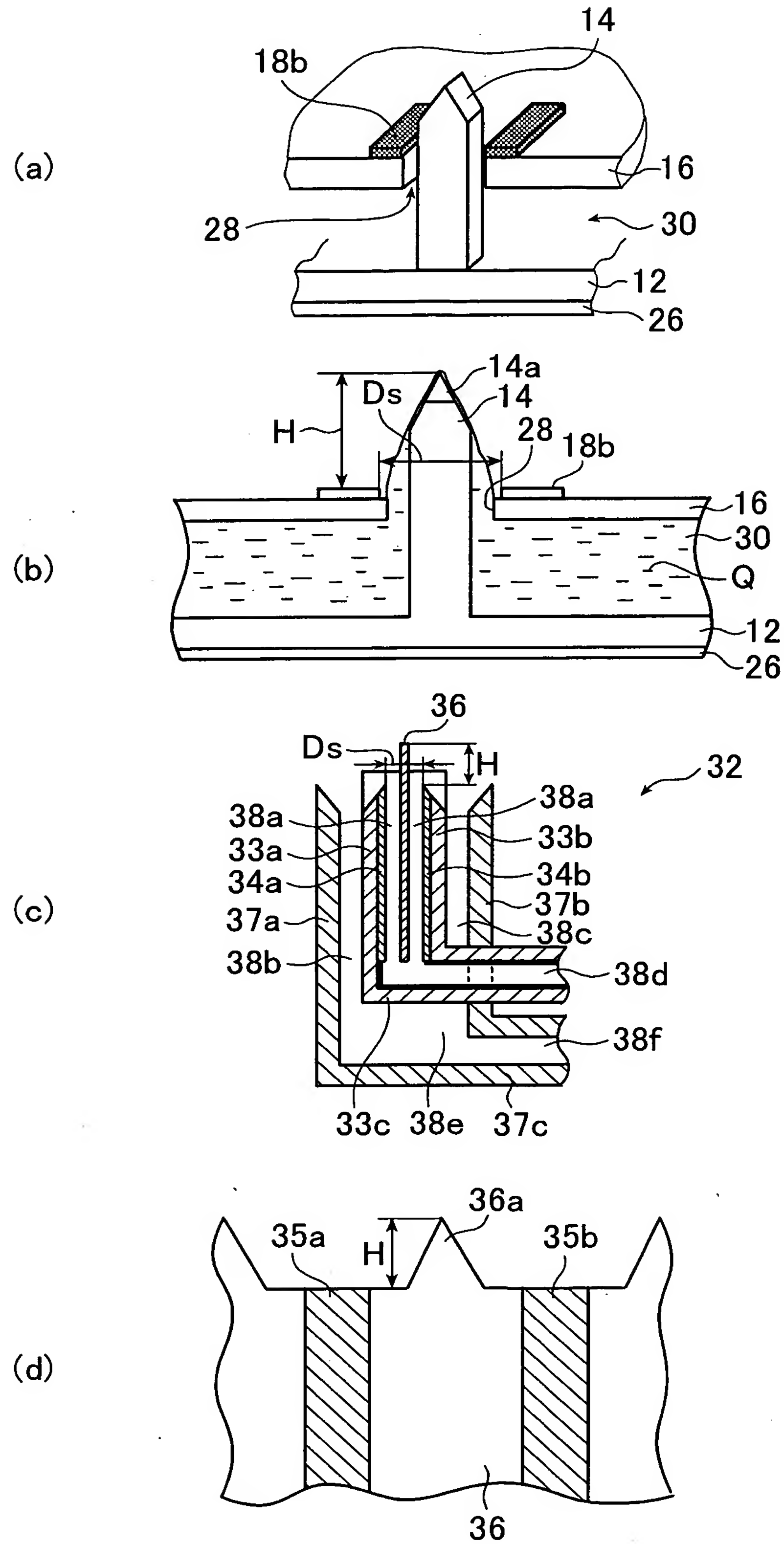
【FIG. 1】



【FIG. 2】

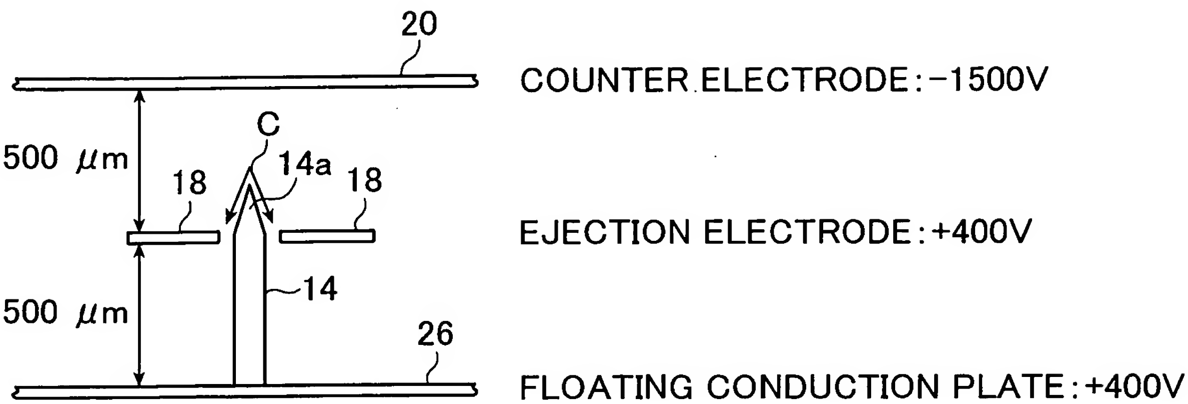


【FIG. 3】

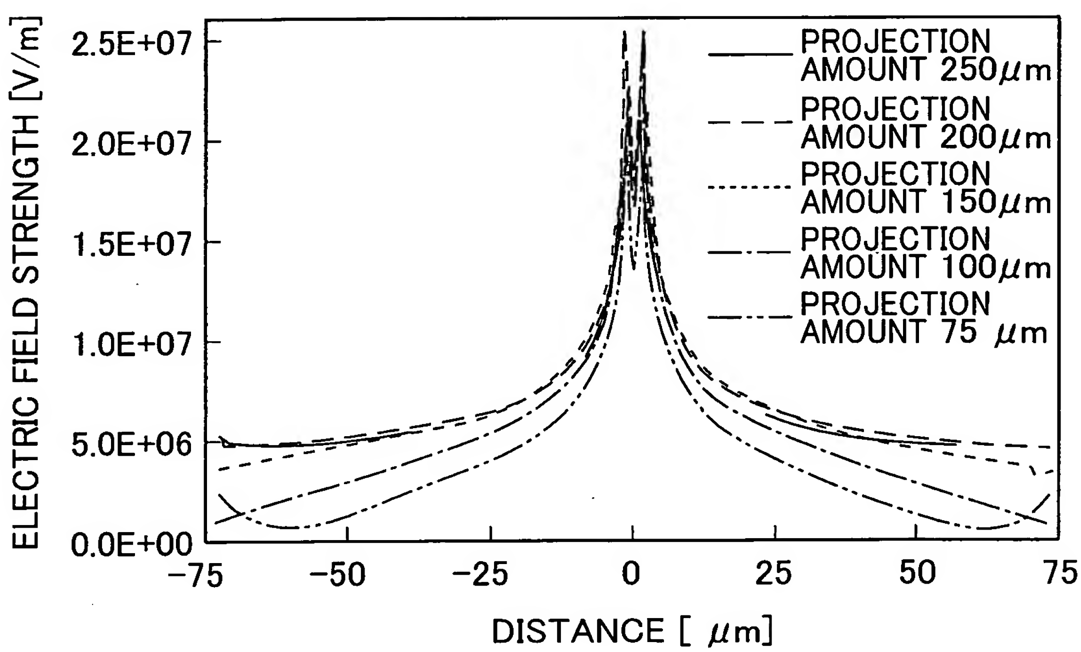


Certificate No. 2003-3073491

【FIG. 4】



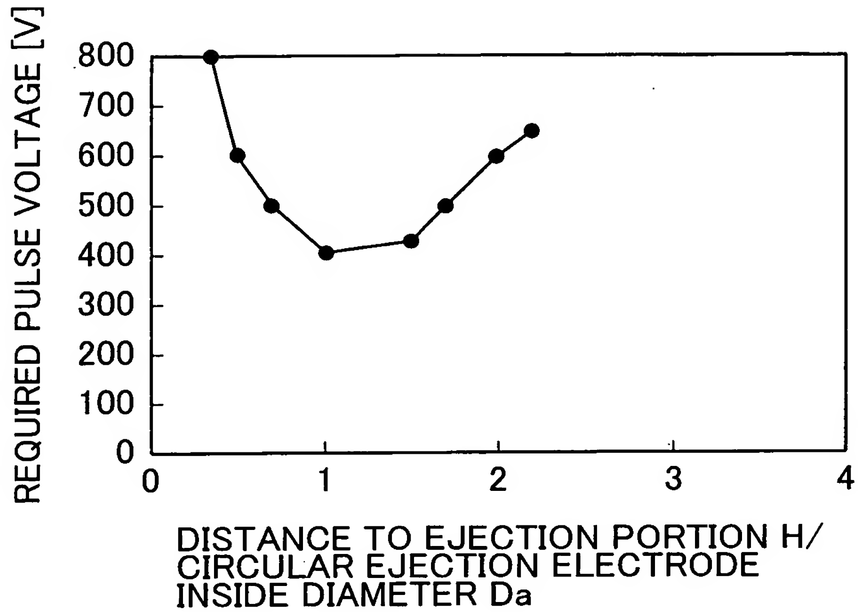
【FIG. 5】



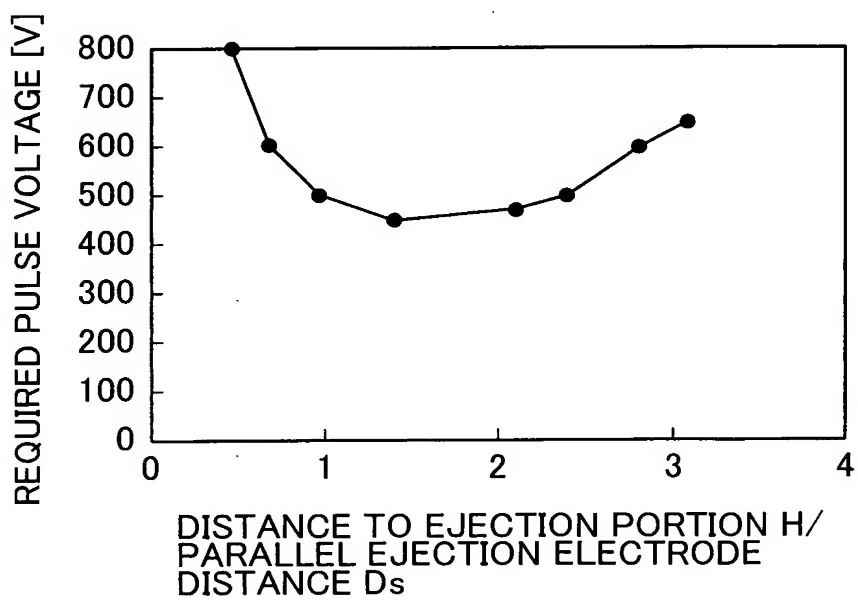
EJECTION ELECTRODE STRUCTURE:
CIRCULAR ELECTRODE HAVING INSIDE DIAMETER OF 200 μm
EJECTION ELECTRODE: +400V, COUNTER ELECTRODE: −1500V,
FLOATING CONDUCTION PLATE: +400V

【FIG. 6】

(a)

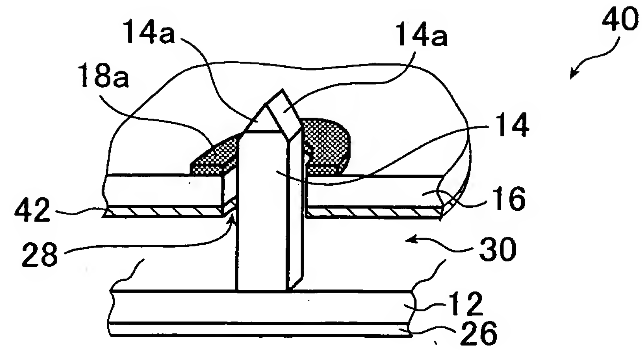

REQUIRED PULSE VOLTAGE [V]
800
700
600
500
400
300
200
100
0
0
1
2
3
4
DISTANCE TO EJECTION PORTION H/
CIRCULAR EJECTION ELECTRODE
INSIDE DIAMETER Da

(b)

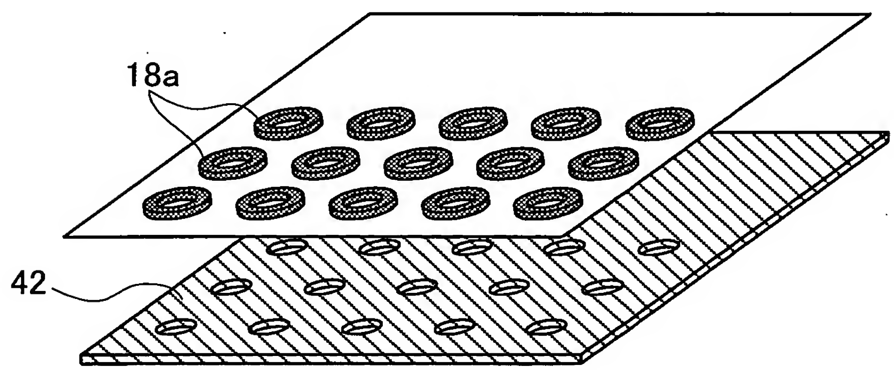

REQUIRED PULSE VOLTAGE [V]
800
700
600
500
400
300
200
100
0
0
1
2
3
4
DISTANCE TO EJECTION PORTION H/
PARALLEL EJECTION ELECTRODE
DISTANCE Ds

【FIG. 7】

(a)

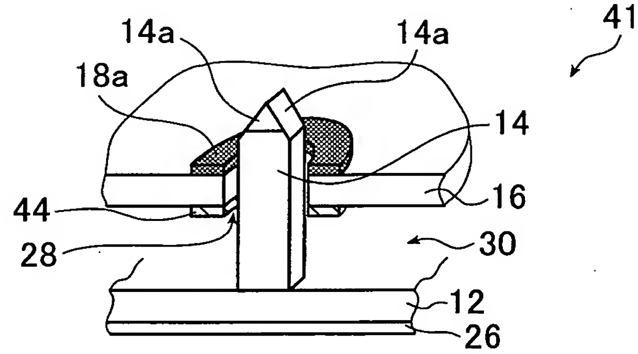


(b)

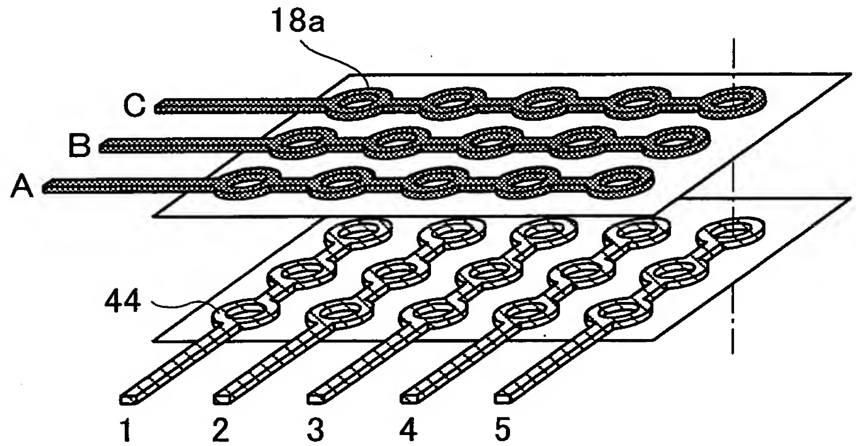


【FIG. 8】

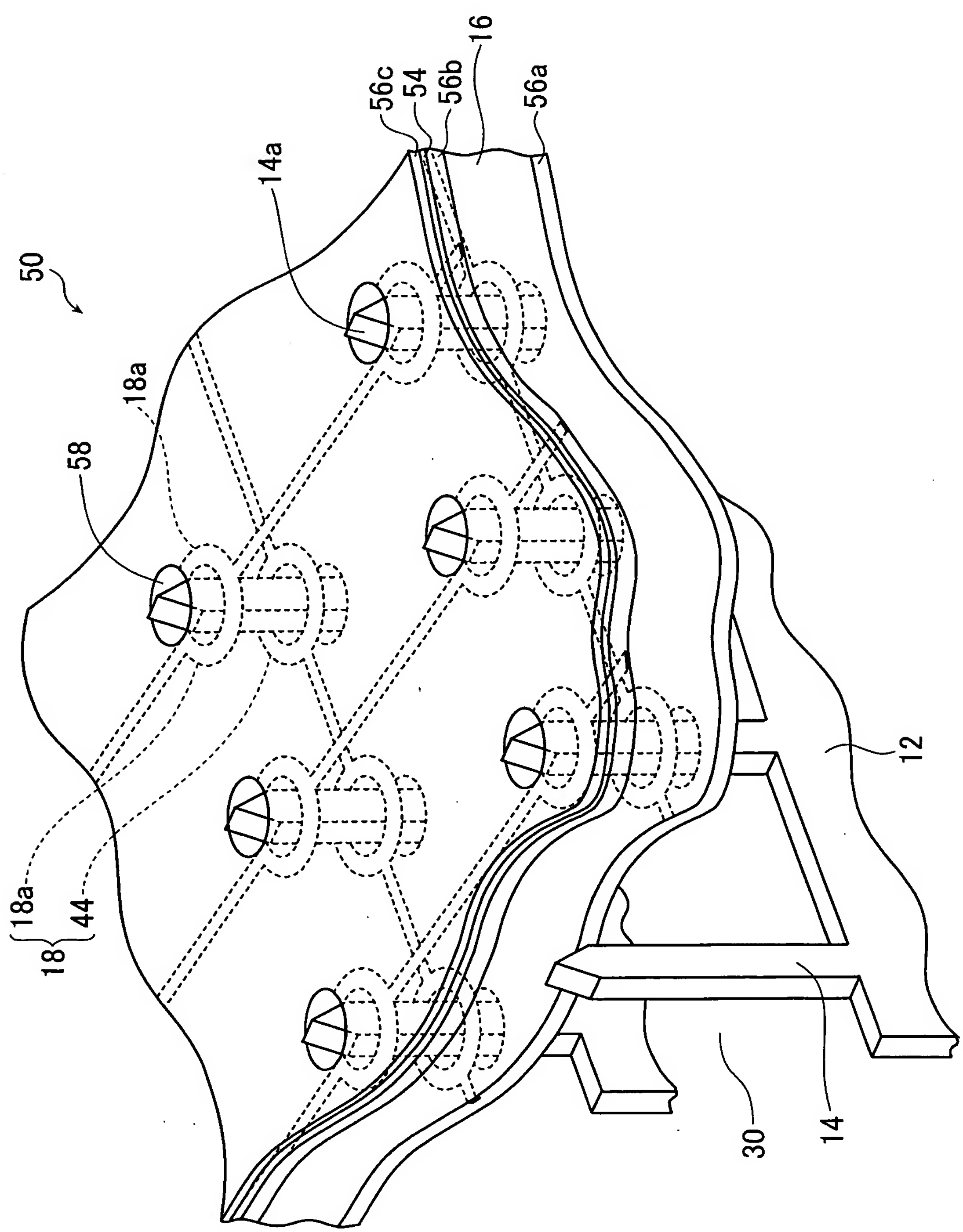
(a)



(b)

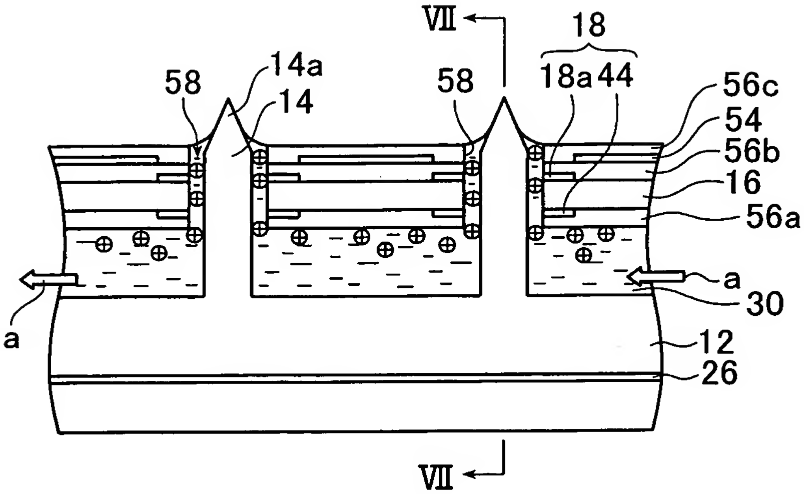


【FIG. 9】

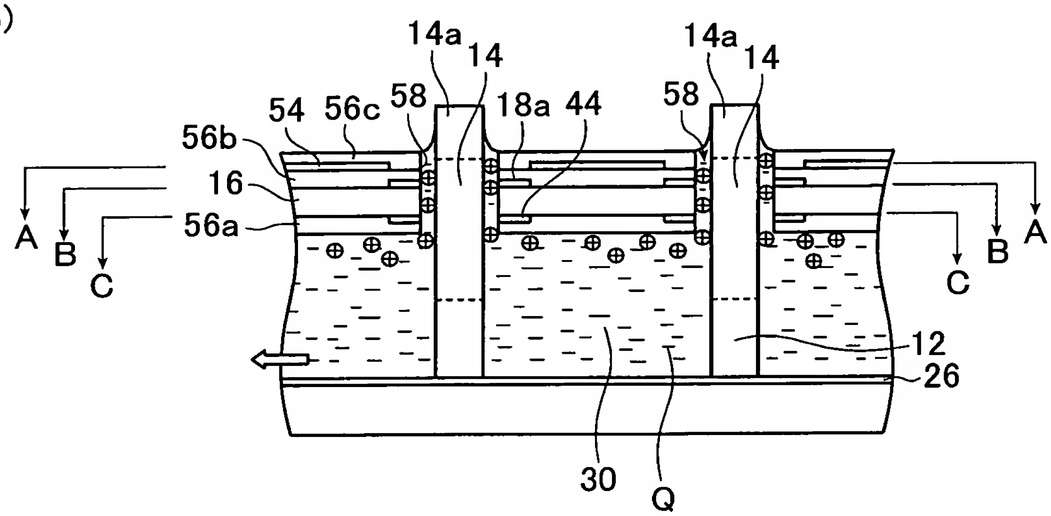


【FIG. 10】

(a)


VII
18
58
14a
14
58
18a
44
56c
54
56b
16
56a
a
30
a
12
26
VII

(b)

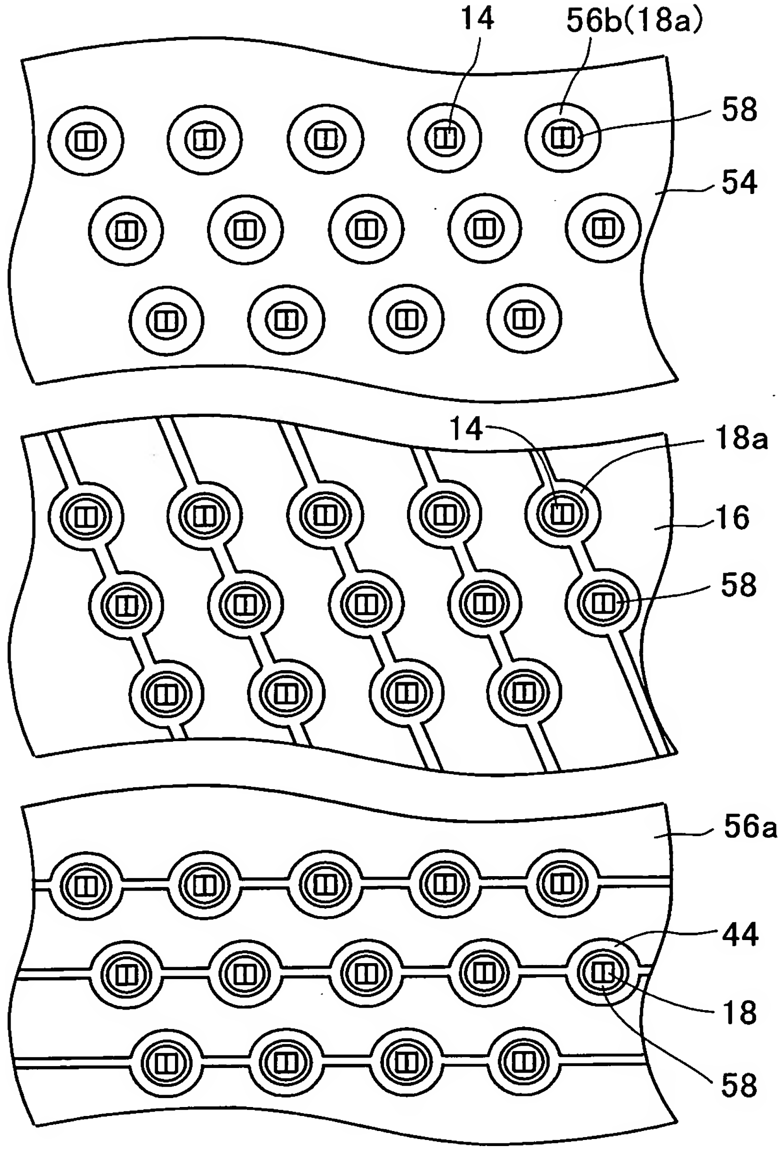

14a
14
14a
14
54
56c
58
18a
44
58
56b
16
56a
A
B
C
A
B
C
12
26
30
Q

【FIG. 11】

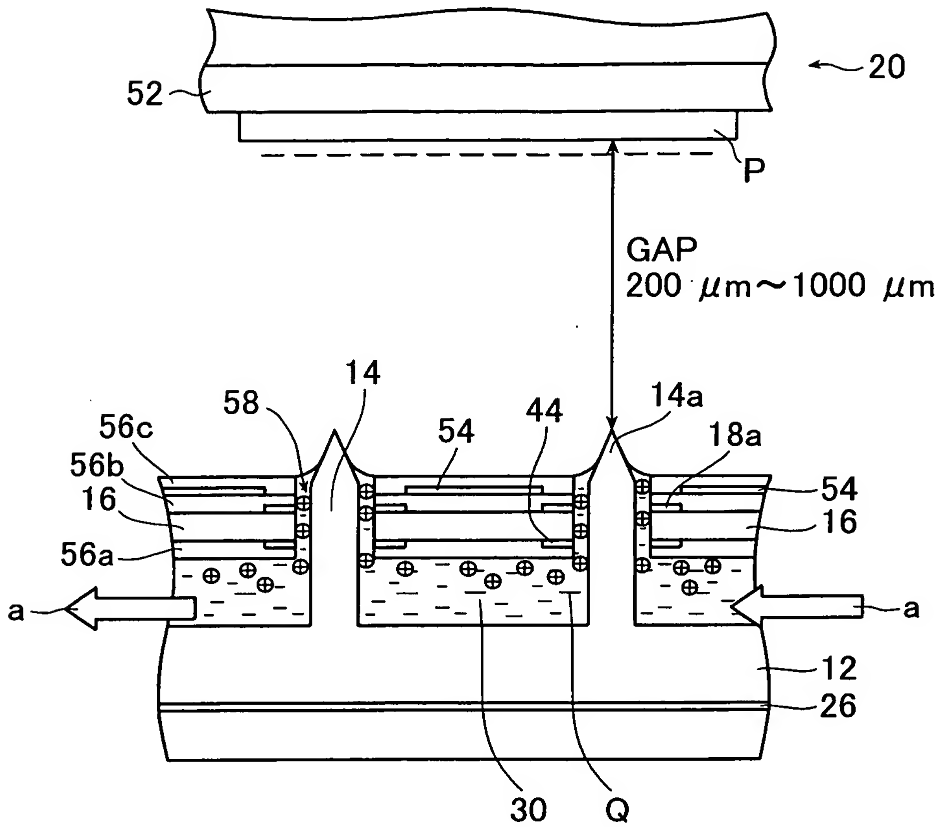
(a)

(b)

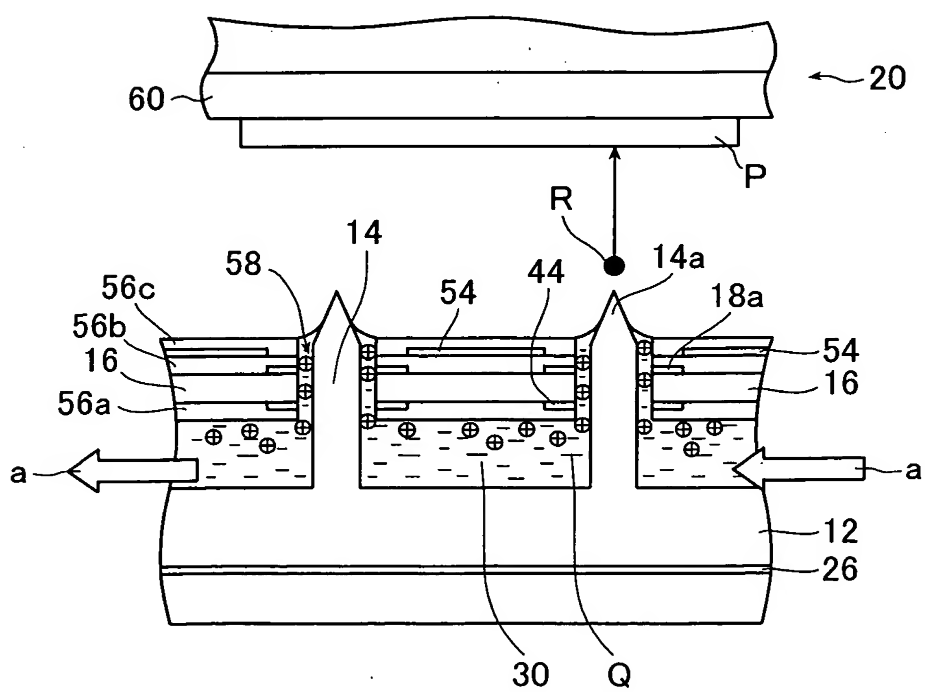
(c)



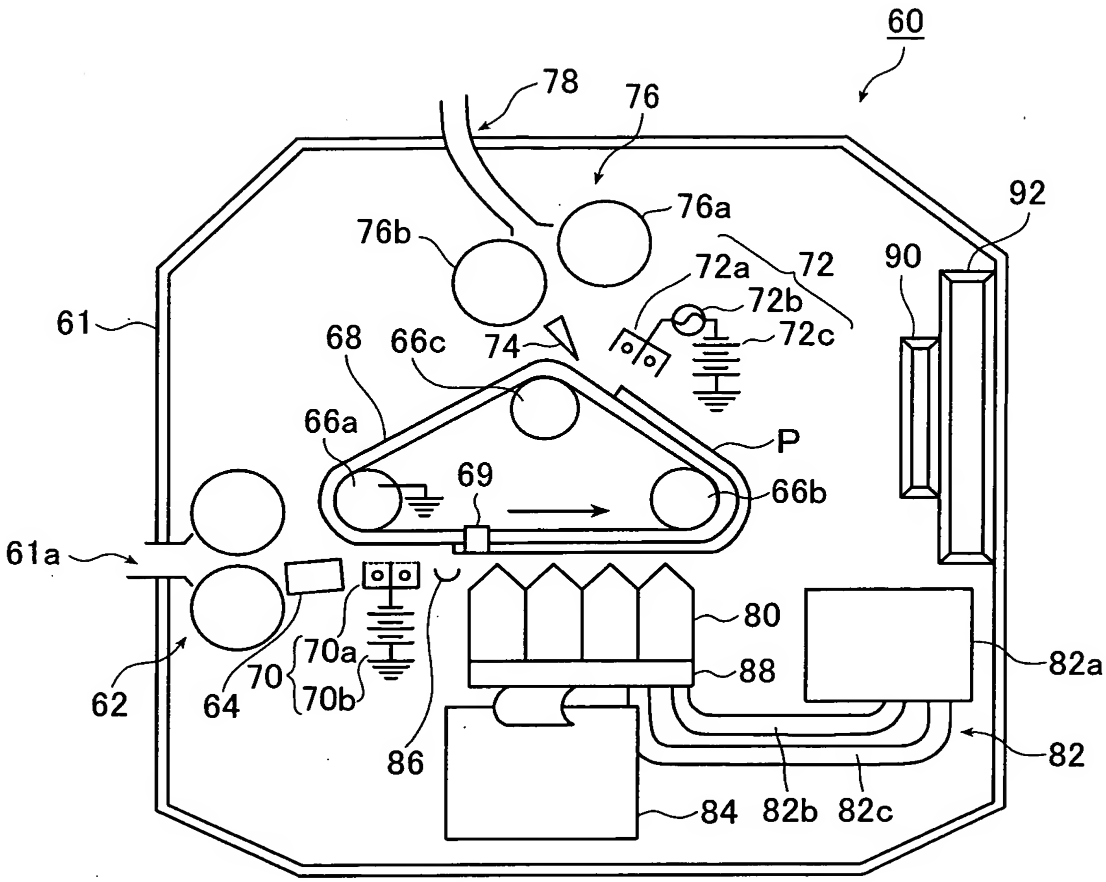
【FIG. 12】


20
52
P
GAP
200 µm〜1000 µm
14
58
54
44
14a
56c
18a
56b
54
16
16
56a
a
a
12
26
30
Q

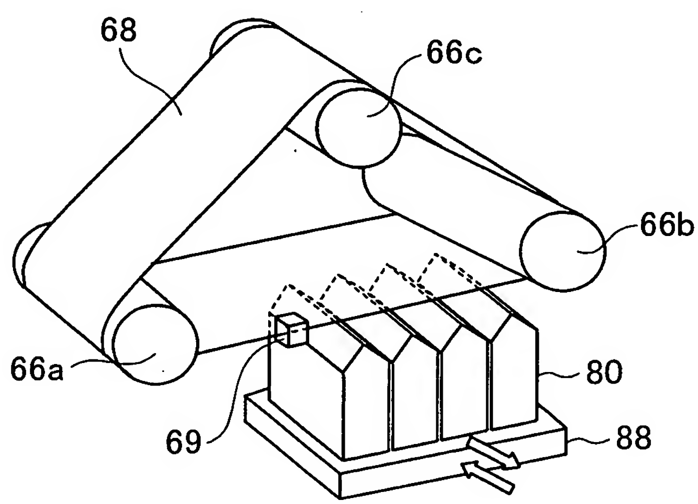
【FIG. 13】


20
60
P
R
14
58
44
14a
56c
54
18a
56b
54
16
16
56a
a
a
12
26
30
Q

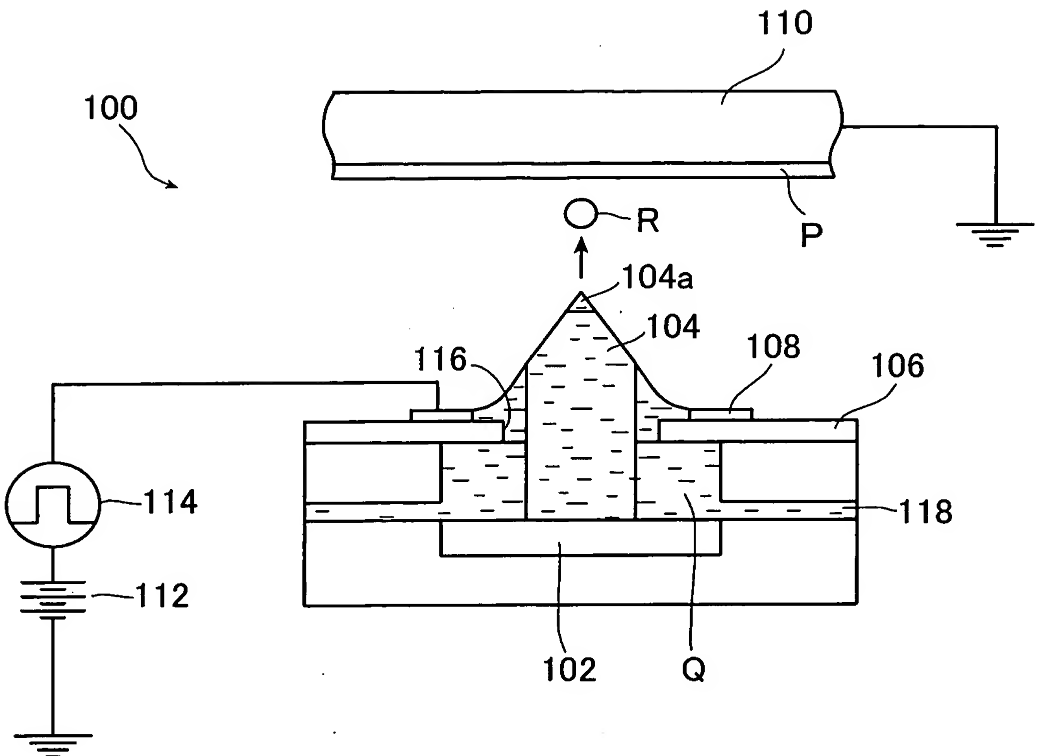
【FIG. 14】


60
78
76
76a
76b
92
90
72a
72
72b
72c
61
68
66c
74
66a
P
69
66b
61a
80
70a
70
70b
88
82a
62
64
86
82
84
82b
82c

【FIG. 15】


68
66c
66b
66a
80
69
88

【FIG. 16】



[TYPE OF THE DOCUMENT] Abstract

[ABSTRACT]

[Subject] To provide an electrostatic ink jet head capable of achieving an ejection voltage reduction, widening a selection range for ink guide materials, and widening a selection range for ink guide tip end structures, and an electrostatic ink jet recording apparatus and recording method using the same.

[Means for solution] An electrostatic ink jet head includes: an ink guide arranged on a head substrate with a tip end portion directed toward a side of a recording medium; an ink flow path that supplies ink to the ink guide; and ejection electrodes arranged to at least a part of an outer periphery of the ink guide at a predetermined interval and adapted to eject the ink guided to the tip end portion of the ink guide by means of an electrostatic force, in which when the ejection electrodes are surrounding electrodes, a ratio between an effective inside diameter of the surrounding electrode and a distance from a surface of the surrounding electrode to a tip end of the ink guide is set in a range of 1:0.5 to 1:2, or when the ejection electrodes are parallel electrodes, a ratio between an effective distance therebetween and a distance from a surface of the parallel electrodes to a tip end of the ink guide is set in a range of 1:0.7 to 1:2.8. Consequently, the above object is attained.

[Selected Drawing] FIG. 2